The University of Alberta

An Analysis of the Liquified Petroleum Gas Industry In Alberta.

A Dissertation Submitted to the School of Graduate Studies in Partial Fulfilment of the Requirements for the Degree of Master of Arts.

Department of Political Economy

Faculty of Arts and Science

By

ROBERT W. WRIGHT

April 10, 1959

Abstract

This thesis is an analysis of the liquified petroleum gas industry in Alberta, with particular emphasis placed on marketing considerations. An outline of existing sources and uses indicates that the production surplus which exists at the present time will continue in the future. Statistical evidence has been obtained from government agencies, major oil companies, and independent distributors. The forecasts made were tabulated from data obtained from the major oil companies and are believed to be the most accurate obtainable.

The supply surplus will result in price instability for the product unless markets can be expanded. This is difficult because the structure of the industry is such that L.P.G. is considered a relatively unimportant by-product. This paper discusses the potential markets and suggests methods by which they can be exploited.

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Sole responsibility for all views expressed, and for any error, is that of the author.

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CHAPTER I

INTRODUCTION

The recent discoveries of oil and gas in Western Canada have undoubtedly resulted in an increased rate of economic development within the region. Although a long run market is assured, the petroleum industry is experiencing difficulty in selling its products because the cost of transportation to the more concentrated areas of the continent is in many cases prohibitive. The resulting surpluses have caused fluctuations in the rate of expansion of the industry over the short run. The purpose of this paper is to analyze the nature of these surpluses with reference to a particular group of products called liquified petroleum gases, and to suggest methods which may possibly result in stabilization of prices and efficient expansion of a consuming market.

THE PETROLEUM RESERVOIR

The petroleum reservoir is a space where petroleum has accumulated together with barriers which prevent its escape. The fluid is found in the pores of particular types of rock, surrounded by an impermeable cap which prevents upward or lateral dissipation. A reservoir is commercially significant when the value of the product which can be recovered exceeds the cost of getting it.

Petroleum is a tremendously complex substance. Basically a mixture of hydrocarbons, it frequently contains carbon dioxide, nitrogen and hydrogen sulfide im significant proportions. The hydrocarbons can vary from the very light gases to the very heavy liquids as shown in Table I.

The products about which we are concerned are propane and butane and are normally produced in association with methane and ethane in a

gaseous form. Thus we must analyze the behavior of natural gas in a reservoir in order to determine how LPG is recovered.

TABLE I

CONSTITUENTS OF PETROLEUM

NAME	FORMULA	BOILING POINT ^{o}F	PRODUCT OF COMMERCE CONTAINING CONSTITUENT
Methane	CH_4	-259	Natural Gas
Ethane	C_2H_6	-128	
Propane	C_3H_8	- 44	L.P.G.
Butane	C_4H_{10}	31	L.P.G.
Pentanes	C_5H_{12}	90	Natural Gasoline Motor Fuel
Hexanes	C_6H_{14}	145	
Tetradecane	$C_{14}H_{30}$	490	Kerosene, Furnace Oil
Tetracontene	$C_{40}H_{82}$	855	Lubricating Oil
Asphaltene	$C_{80}H_{162}$	1200	Asphalt, Bunker Oil

SOURCE: From E.W. Zimmerman. Conservation in the Production of Petroleum. P. 57.

Natural gas has no consistent composition. If it contains significant amounts of vaporized liquid components (propane, butane or pentanes) it is termed "wet gas", and if it contains large amounts of sulphur compounds it is termed "sour gas". The composition of gas from typical wells in the major fields in Alberta is shown in Table II.

TABLE II

PERCENTAGE COMPOSITION OF THE NATURAL GAS

IN SELECTED POOLS IN ALBERTA

	Methane	Ethane	Propane	Butane	Pentane	Nitrogen	CO_2	H_2S
Viking Kinsella	89.4	1.7	.8	.4	7.5	-	-	-
Jumping Pound	83.9	4.0	1.0	.7	.7	-	6.1	3.6
Leduc Woodbend								
D-3:Gas Cap	82.4	11.6	4.5	-	1.5	-		
D-3:solution	66.9	16.8	8.8	2.9	1.0	2.8	.8	
D-2:solution	69.9	11.5	5.8	2.2	.5	4.1	1.1	4.9
Pincher Creek	76.6	3.1	1.3	.8	.6	1.4	5.0	11.2
Pembina	76.1	8.8	8.2	2.8	.8	2.9	.3	-
Redwater								
D-3:solution	64.4	14.8	8.1	2.9	.6	2.5	4.0	2.7
Fenn-Big Valley	49.7	11.0	10.1	4.2	1.3	9.2	11.8	2.7

SOURCE: From E.J. Hanson, Dynamic Decade, pp. 237. Original data from Oil and Natural Gas Conservation Board, Province of Alberta.

The volatile materials dissolved in oil are kept in solution by the pressure and temperature prevailing in the reservoir. If the amount of gas exceeds that which can be held in solution by the temperature and pressure, the excess exists as a free gas usually occupying the dome of the reservoir. A typical reservoir with a high gas-oil ratio is illustrated in Figure I.

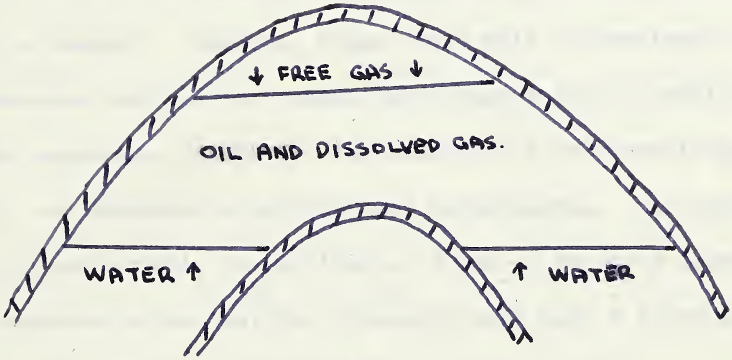

FIG. I. A TYPICAL RESERVOIR

At discovery, petroleum reservoirs are under pressure, so to maintain production the pressure in the well must be kept lower than that in the reservoir so that the water or expanding gas can drive the liquid to the surface. As pressure is reduced, there is a tendency for dissolved gas to become free and it occupies the pores vacated by the oil and is usually swept up with the flow of oil to the surface. In reservoirs which are predominantly occupied by gas, recovery is usually by simple expansion when pressure is released. If the gas is wet, expansion may result in the liquification of the condensate (heavier hydrocarbons including propane and butane) within the formation. To recover these

heavier ends a cycling operation is often inaugurated in which the wet gas is extracted, distilled to remove the heavier ends, and the dry gas is pumped back into the formation. Thus, gas can be produced from three sources: gas reservoirs, gas in association with oil, or from free gas in oil reservoirs.

When a field is discovered, tests are run to determine the composition of the petroleum in the reservoir. If gas will be the primary product the well is usually capped because in Alberta existing supply is in excess of demand. However, a gas field will be developed if particular circumstances warrant it: where heavy ends exist in sufficient quantity to make separation feasible; the quantity of recoverable gas is great enough; or location is particularly advantageous. At the present time a well will not usually be profitable if gas is the sole source of income. Every operator hopes that his discovery will have a large proportion of oil, for that is the product which is easiest to sell.

In any event, if some product exists in sufficient quantity to be commercially significant, the operator petitions the Oil and Gas Conservation Board to go into production. Permission is normally granted on the proviso that the operator follows the recommendations of the Board regarding (1) methods of withdrawal and (2) disposal of by-products. If the petroleum in the reservoir is heterogeneous and the cost of separating the by-products is not in excess of their value, the Board usually suggests that separation facilities be constructed. If the cost is too high, the by-products are flared. The supply of LPG is therefore determined by its existence in commercially significant quantities in producing oil and gas fields and by the rate at which these fields are developed.

The demand for gasoline and natural gas are the primary determinents of the rate at which development will be undertaken. Gas, being light and volatile, moves freely within a reservoir so that the migratory characteristics are particularly pronounced. In addition it cannot be stored economically above ground, so that production in the absence of a ready market can cause the loss of great amounts of a very valuable substance. Nevertheless, supply is constantly increasing because most gas wells are discovered by people looking for oil and the production of casinghead gas is an inevitable incidental to oil production. Thus the supply of natural gas from oil fields is determined primarily by the demand for oil.

A continuous, long term growth of consumption of petroleum products is predicted by most experts. The Royal Commission on Canada's Economic Prospects, 1957, estimates that by 1980, Canadian petroleum production will be 8.5 times that of 1955, while natural gas production will increase 16 times in the same period.(1) New markets will develop as population and mechanization increase, pipeline facilities are expanded, and the U.S.A. is forced to import more crude as her own fields become depleted. Thus, the demand for Western Canadian crude may be subject to short run fluctuations but a long run market is assured. We may conclude that the supply of LPG will increase and continue to be adequate, if not excessive, to meet normal demand. Statistical verification of this conclusion may be found in Chapter III.

As long as petroleum production is aimed at satisfying a demand for which there is little competition (motor gasoline), the invasion of

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(1) John Davis, Canadian Energy Prospects, a report preparatory to the Royal Commission on Canada's Economic Prospects, 1957, 7.

competitive markets by by-products and co-products has to be accepted as an inevitable corollary, for it fortifies the position of the primary product. We must therefore determine what markets our particular by-product - LPG - can obtain and maintain against competition. This is discussed in Chapter IV.

CHAPTER II

THE EFFECT OF CONSERVATION POLICY

The petroleum industry in Western Canada is comprised of many types of firms varying from large integrated companies to small independents concerned with a single operation. In addition, some firms have holdings in many fields whereas others have their holdings confined in a small area. The resulting variations in capital invested and the richness of reserves held cause a great difference with respect to desired policies regarding rate of extraction. Generally speaking, the smaller firms lack financial reserves and desire rapid extraction, whereas larger firms will limit production if future prices are expected to be advantageous.[1] Without some regulatory mechanism, these differences in policy could have many unstabilizing effects including (1) market gluts if the representative firm[2] did not have a sound long term financial position, (2) unnecessarily high prices if an oligopoly situation developed or (3) wasteful withdrawal from the reservoir. Society has decided that it cannot afford to rely exclusively on the free play of market forces for optimum development of the industry. The result has been the establishment of government agencies to control all aspects of production. In Alberta, this agency is called the Oil and Gas Conservation Board.

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[1] In "Unstable Conditions of Competition and Monopoly in Exhaustible Resource Industries", Journal of Political Economy, Vol. 50, 1942 pp. 739, et. seq., W.J. Pabst analysed the American Anthracite coal industry and concluded that changes in expectations as to future prices have profound effect on the structure (degree of monopoly) of a resource industry. When expectations become pessimistic, the value of unexploited reserves falls accordingly. However, this drop in value does not affect the independent as much because he is not afraid of spoiling the market by expanding operations. As a result, when available supply exceeds effective demand the independent gains a larger percentage share of the market.

[2] Alfred Marshall, Principles of Economics, (8th ed., London, 1920), Book V.

Three of the major purposes of the Conservation Board are: (1) prevention of sub-surface wastes, (2) protection of property rights, and (3) adjusting supply to effective demand to minimize above ground wastes.

Unrestricted production causes premature dissipation of the expulsive forces within a reservoir with the result that too much oil which cannot be recovered is left behind. If gas in association supplies the drive then pressure usually gives out early in the life of the well, and there is scope for secondary recovery methods, whereas if gas caps supply the pressure, it is easier to maintain. There are several indices of efficiency including (1) rate of drop in pressure, (2) excess of gas-oil ratio in excess of the amount of gas in association, (3) if water production is abnormally high it indicates irregular advance on the interface[3] so that pockets of oil are formed which are difficult to recover.

Because pools are owned by many producers, regulation is necessary to protect each against practices of neighbors which cause sub-surface drainage to adjacent wells. To counteract migration, operators may be inclined to drill offset wells too close to proven wells. As this may decrease pressure and thus affect ultimate recovery, restriction is necessary.

Price stability is essential to the industry for it permits long term planning and minimizes risks. The assurance of a long term market results in the orderly expansion of communities located in producing areas.

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[3] interface - area of contact between oil and water, or oil and gas.

Because of the scarcity of volume markets for crude oil, the Board attempts to restrict supply to the demand existing at a price which is expected to yield normal profits.

Adherence to the "rule of capture" usually results in alternate periods of overproduction and low prices. These fluctuations would be harmful to the welfare of the region and the industry[4]. In an effort to be equitable to all producers, yet still provide incentive for further exploration and drilling even though present demand may not seem to warrant it, the Board has developed a system of "Prorationing".[5] At discovery each well is assigned a maximum permissible rate (MPR) based on engineering estimates of the most efficient rates of production for the reservoir in question. The Board then estimates purchasers' requirements and if it is found that the expected demand is less than the aggregate MPR of all wells in the province, the output is rationed on a two-part system. Each producing well is assigned an "economic allowable" which is based primarily on the depth of the well and which is designed to insure that each well will be able to sell enough oil to recover the costs of drilling, maintenance, etc. If the total economic allowables for all wells is not enough to satisfy the existing demand, the balance is assigned on the basis of reserves. This, of course, allows the owners of richer wells to sell more than the well owners possessing smaller reserves. This policy is accompanied by restrictions concerning

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[4]A.G. Pigou, Industrial Fluctuations, (2nd ed., London, 1929), 239.

[5]Prorationing is defined as the allocation of effective dem and amongst competing producers on a pro rata basis.

well spacing so that producers are prohibited from sinking additional wells simply to increase their allowables.

A custom which is common in the United States and subject to increasing interest and investigation in Canada is the practice of unitization, or co-operative exploration and development of pools under common management. It is applicable in two situations:

1. To facilitate recovery procedures designed to increase the ultimate recovery, which procedures either could not be carried out individually because of the cost involved, or if carried out individually would disturb the ownership rights of the common pool. Included in these procedures are secondary recovery and artificial maintenance.
2. If demand falls short of available supply, a unitized field can shut in marginal wells and by concentrating production, duplication will be minimized so that the total costs are reduced but the total marketable output is maintained.[6]

Although unitization is the theoretical answer to many of the industry's problems, it is hard to put into practice because of the difficulty of obtaining the approval of all operators.

There is conflict among theorists as to whether conservation results in a higher or lower long term price for the product. However, it is generally agreed that it is in the best interests of society that

[6] S.E. Buckley. Petroleum Conservation, (New York, 1951), 227.

prices be not unduly depressed by overproduction to the point where it no longer pays to make the fullest use of efficient methods compatible with the current state of the arts and of scientific knowledge.

Conservation as practiced by the Board is primarily concerned with the equating of supply and effective demand for the major products - oil and natural gas. However, it does not follow that by-products, such as LPG, will benefit from this stabilization. Because the composition varies greatly from field to field, it would be impossible to regulate the output of all products. LPG is therefore considered as a residue, and left to fend for itself under conditions of unrestricted competition.

Price Determination

A high recovery of petroleum resources is imperative because the cost of exploration and development constitute the bulk of total costs of crude oil and its by-products. There remains the problem of determining how these direct development costs are apportioned to the various products in fixing relative wellhead prices.

The supply of crude oil is determined by the demand for the primary product - gasoline. Its demand is, in turn, derived from the demand for the services which it provides. These services are constantly increasing as population rises and our society becomes more mechanized. Within normal limits the market demand for gasoline is inelastic for the following reasons: (1) there is little scope for substitution (2) consumption cannot be postponed (3) the market is composed of a large number of small volume users so that fuel costs are relatively insignificant. Where substitution is possible it is usually limited to products

from the same industry and even then the specialized high priced durable equipment makes it difficult. The result is that the expected well head price of crude is high enough to absorb all the normal costs of exploration and development.

The supply of natural gas varies with the demand for oil. In Alberta, local demand (primarily for space heating) is inadequate to absorb potential output, and transmission to distant markets is prohibited by high pipeline costs. The result of this excess supply is that prices are very low and are not a true reflection of its calorific value in relation to other fuels even though higher market prices would seem possible because of its convenience. Supply is not usually aggravated by the discovery of a gas field for the new wells may be capped. However, when gas is found in association with oil it must be produced as a by-product and as such takes on typically unorthodox market characteristics. The temptation to sell gas at low prices is fostered by conservation rules which dictate that gas which is produced must be marketed if it can be done without loss. If an operator must gather the gas or shut-in the well,he is likely to accept a very low price for gas.

What effect does the price of crude oil and natural gas have on the well head price of LPG? As crude prices normally absorb the cost of exploration and development, the operator will be willing to sell LPG at any price which is in excess of the cost of separating and processing. It is prevented from rising above this minimum by two factors: (1) an almost perfectly elastic supply and (2) whereas many of the heavier products have a complementary relationship with the major product, LPG is competitive, not only with other petroleum products, but with almost all fuels.

CHAPTER III

EXISTING SOURCES AND USES OF L.P.G. IN WESTERN CANADA

Liquified petroleum gas is a hydrocarbon gas which can be easily liquified at normal temperatures by moderate pressure. Consequently, it can be stored or transported as a liquid and used when needed as a gas. It consists of propane or butane or mixtures of the two. The products can be obtained naturally from petroleum reservoirs or as a by-product from refineries.

TABLE III

PHYSICAL PROPERTIES OF PROPANE AND BUTANE

	PROPANE	BUTANE
Formula	C_3H_8	C_4H_{10}
Molecular weight	44.094	58.12
Boiling point	43.8F	31.1
Weight of liquid at 60°F in lbs. per imperial gallon-	5.08	5.84
Heat of combustion in B.T.U./cu. foot at 60°F -	2521	3267

Source: G.A. Purdy, Petroleum, p.287

LPG is extracted from natural gas in absorption plants. These consist of two towers, in the first of which the heavier components including propane and butane are absorbed by a lean oil and the dry gas goes off. In the second tower, the LPG is separated from the oil by fractional distillation. When produced at refineries it is the result of the distillation of crude oil.

Table IV (see Appendix A), gives the estimated production and sales of propane in 1957. Alberta produces 77% of the Western Canadian output. The figures only show the output of gas plants as the product produced by Alberta's refineries is not marketed, but is used in the refineries. In the other three provinces the refineries supply the market as the natural gas fields are not sufficiently developed to warrant gas absorption plants. The output of 1,442,000 barrels was not up to original expectations. Technical difficulties at Taylor Flats, B.C., and Stettler, and reduction of crude allowables during October, November and December resulted in this shortage.

Total sales of domestic production were 1,050,000 barrels with imports from the U.S.A. amounting to 211,000 barrels. These imports were made necessary by the combination of two factors: (1) lack of storage facilities, and (2) the highly seasonal demand. As production is relatively constant all year round, there was deficiency in the winter months. As construction of additional storage space is being planned, it is felt that imports will not be necessary in the future. It will be noted from Column 3, that Alberta supplies considerable quantities of propane for Saskatchewan and British Columbia.

Table V (Appendix A) gives 1957 butane production. All the butane produced was refined in Alberta by Gas Conservation Plants except 14,000 barrels made available by Co-op. Refineries in Saskatoon and 112,000 barrels by Imperial Oil Limited, Calgary. The product which was not sold was used as boiler fuel.

The value of the total Western Canada output in 1957 was in excess of $4,000,000. This represents considerable progress for an

industry which started only 10 years ago. Figure II shows Alberta's output for the period 1948 - 1957, and it can be observed that the industry has developed at a relatively steady rate. Thus 1957 can be considered a representative year. Table VI (Appendix A) shows the disposition of the output. About 80% of total output of propane is made available to the market, with the balance being lost, flared or used by the producing company. Because of an inadequate market in 1957, 10% of the total output was stored underground. The propane sales figure of 789,000 barrels is considerably below the figure of 933,000 barrels estimated by the Conservation Board. The discrepancy is accounted for by the fact that the Board includes inter-departmental transfers within the same company as "sales", whereas these figures do not.

In the case of butane, 77% of the total output was made available with 19% of the total being stored.

Table VII (Appendix A) gives a breakdown of the end use of the production of Alberta in 1957. Figures for the other provinces are not included but it is felt that Alberta's figures are representative as this province is by far the major producer.

With these production and sales figures as a basis, we proceed to a discussion of the industry as it exists at the present time.

The original decision to construct a gas absorption plant is made by the Conservation Board. When a field is developed, tests are run to determine the quantity of gas available, as well as an analysis of the components. If the gas is wet enough and if the gas allowables are expected to be sufficient to make a gas absorption plant economically

feasible, the fact is suggested to the owning company. In making their decision the Board considers the market in relation to the existing supply, but their primary concern is to prevent the product from being wasted.

Once the plant is constructed and output commences, the next problem is to get the product to the market. There are three possible methods: pipeline, tank car, or tank truck. In Alberta, the only LPG pipeline is from Devon to Edmonton. The rest of the product is delivered by rail or truck. Because of the shortage of railway tank cars, and because of the high initial cost involved in providing railroad facilities for oil fields, many of which are in rural areas, most of the product is moved by tank truck. If the product is sold to large users it is delivered at a stipulated price according to long term contracts. Thus the producer has a reasonably accurate estimate of what demand will be. However, when the purchasers are the smaller distributors who sell to the rural market for domestic consumption, they buy the product as they need it and daily demand is difficult to estimate. Also, output cannot be predicted with any degree of accuracy, as it depends on gas allowables and they are subject to change. Thus it can be seen that storage facilities are needed at the gas plants.

In October, 1956, the Conservation Board suggested to the LPG Association that additional storage facilities should be constructed to ensure adequate supplies of propane to Alberta consumers in the winter months. This has not been followed up and storage facilities are still unsatisfactory. Because of the highly seasonal demand, more storage facilities are essential for satisfactory development of the industry as

insufficient storage invariably leads to wasteful flaring in off-peak periods. Experienced producers suggest a minimum storage of seven times daily capacity at the producer level, and two weeks peak winter demand at the distributor level. Table VIII (Appendix A) gives the storage capacity in Western Canada and Goliad is the only major producer in Alberta which has more than adequate storage facilities. This is probably a result of the interest shown in using LPG for miscible flood operations in the Pembina field. A plan for using natural underground reservoirs in the Hardisty district is also under consideration.

The largest propane producer in Western Canada is Imperial Oil Limited, which is responsible for 33% of the total sales. The next largest are Texaco (20%), B.A. (12%), and Royalite (10%). There are seven producing companies, but because of location factors, and high costs of transportation, the competition is not severe except in the Edmonton area.

Imperial Oil Limited is the largest producer of butane and their market position is further enhanced by their contracts with Canadian Chemical Limited, which is the largest consumer. As a result, they control 64% of the market.

The largest user of propane is the rural domestic market. The farms use propane for spot heating, refrigerators, tractors, space heating and a variety of other uses. This market is serviced by a variety of distributors of which Canadian Propane Limited is by far the largest. These distributors have a field staff which sells the specialized equipment necessary and a delivery system which supplies the farms regularly. The product is delivered in a liquified form in pressurized tanks. Canadian

Propane Limited and its associated company, Sturdie Propane Limited, distributed approximately 70% of the propane marketed in Alberta and B.C. In 1957, C.P.L. sold over 12,000,000 gallons through its 20 branches. The largest of the other distributors are Mutual Propane (Edmonton), Rockages (B.C. interior), and Propane Engineering (Calgary). These distributors compete with each other in the more concentrated areas, but most of the smaller towns only have one supplier. Competition does not seem to take the form of price competition, but is restricted to sales and servicing programs.

Canadian Chemical Limited uses considerable quantities of butane and propane and purchases it as a mixture as well as in the purified form. In this market, price competition determines the supplier, and I.O.L. has up until now controlled this area because their refinery has the largest capacity and thus has had a production cost advantage over other suppliers. As C.C.L. will accept mixtures, propane and butane from field plants must compete with refinery gases. Of the total market 65% is supplied by field plants and 35% by refinery gases. This is a good outlet for seasonal surpluses. In 1957, I.O.L. sold 1.5 million gallons of propane and 2.5 million gallons of butane at reduced prices during the summer months.

The LPG surpluses of the Pembina field have found use as a miscible flood gas. However, this use is restricted to fields which are experiencing difficulty in obtaining satisfactory pressure, and this is a rather uncommon occurrence.

Butane is also used at the Calgary refinery and "reformed" to obtain the isobutane required in the alkylation process. It is also shipped by tank car from Calgary to the Pacific Coast for use as a peak

shaving gas in natural gas distribution systems. Tables IX, X and XI (Appendix A) are forecasts of production and markets for Western Canada for the period 1958 - 1961. The production figures are an estimate of what would be available under normal conditions, if a market existed. Table IX (Appendix A) shows that the amount available greatly exceeds demand, so that actual output will be far short of potential.

Conservatively it is estimated that Western Canada will produce 65 million gallons of propane in 1958. As the domestic market demand has a ratio of 2.1 for winter and summer, the output of 65 million will mean that supply and demand will be equal in the winter months (33 million gallons) and there will be a 15 million gallon surplus in the summer months.

Actual production of butane will approximate 40 million gallons which should be adequate to cover the estimated demand of 31 million gallons. Butane demand is less seasonal than propane because of the relatively steady demand of Canadian Chemical.

Demand figures are based on a conservative 10% increase per year. This figure may be arbitrary but it is expected to be reasonably realistic. In actual fact it is not too important because even at a 20% yearly increase there would be a considerable surplus of supply.

Thus the state of the industry may be summarized as follows:

Output is controlled by the major oil companies. The quantity of output is dependent on the demand for oil and natural gas. There is an area of conflict between the companies and the government. The companies do not wish to invest in the extracting and distribution facilities unless it returns a normal profit, and if LPG output increases at its anticipated rate, supply will exceed demand to such an extent that

prices will be depressed to the point where this profit is unattainable. On the other hand, the Conservation Board does not want the product wasted and so demands that output facilities be expanded in spite of the fact that storage is feasible only for short periods.

The major buyers of propane are the distributors for rural consumption. There is one firm, Canadian Propane Limited, which dominates the industry, but the group as a whole is not progressive. They let the oil companies bear the risk and buy the product as they require it, thus minimizing their own costs. Their efforts are restricted to routine selling and distribution, and little technical or market research is undertaken. Probably the ease of entry acts as a deterrent to existing companies to effect improvement. Other purchasers of propane, and all butane buyers, obtain the product directly from the producing companies for their own particular needs. Each contract is negotiated separately and there does not appear to be any conflict between distributors and direct purchasers.

The most immediate problem confronting the industry is to bridge the gap between demand and available supply. New or expanded uses must be discovered - the alternative is waste. Were it not for this uncontrollable production surplus, the industry could be described as a normal, young industry experiencing the usual transitional difficulties - in this particular case the most important of these shortcomings are (1) lack of storage facilities, (2) fear of financing research, and (3) absence of industry wide coordination.

It can therefore be concluded that supply will not be the limiting factor in the expansion of the industry. The areas which will require the most attention are distribution and marketing.

With these facts in mind, we turn to a discussion of the various possible uses of propane and butane. Once the alternatives have been analysed we will attempt to determine which of the possibilities will be applicable to the Western Canadian situation.

APPENDIX A

TABLE IV

TOTAL PRODUCTION AND SALES OF PROPANE IN WESTERN CANADA, IN 1957 (BY PRODUCERS) IN BARRELS

	ESTIMATED PRODUCTION	ESTIMATED SALES	CONSUMPTION
BRITISH COLUMBIA			
1. Standard of B.C., Vancouver	57,140	51,430	
2. Shell - Vancouver	85,710	74,280	
3. Royalite - Kamloops	8,570	7,140	
Provincial Total	151,420	132,850	354,000
ALBERTA			
1. Progas, Acheson	75,300	51,430	
2. Texaco, Bonny Glen	329,760	214,290	
3. B.A., Stettler	101,220	82,850	
4. Royalite, Turner Valley	150,570	85,710	
5. I.O.L., Devon	333,150	261,770	
6. I.O.L., Redwater	121,360	84,970	
Provincial Total	1,111,360	781,020	617,000
SASKATCHEWAN			
1. B.A., Moose Jaw	57,140	50,610	
2. Royalite, Saskatoon	14,290	11,430	
3. Co-op, Regina	37,140	28,570	
Provincial Total	108,570	80,610	240,000
MANITOBA			
1. North Star, Winnipeg	71,430	56,710	50,000
TOTAL	1,442,780	1,050,190	1,261,000

Source: Tabulated from data obtained from interviews with personnel of various firms in the oil industry.

TABLE V

TOTAL PRODUCTION OF BUTANE IN WESTERN CANADA, IN 1957, IN BARRELS

	ESTIMATED PRODUCTION
1. ALBERTA	
1. Gas Plants	
1. Progas, Acheson	39,660
2. Texaco, Bonny Glen	233,537
3. B.A., Stettler	90,250
4. I.O.L., Devon	263,710
5. I.O.L., Redwater	119,160
6. Wizard Lake	1,400
	747,710
2. Refineries	112,440
	860,150
2. SASKATCHEWAN	
1. Co-op, Saskatoon	14,290

TABLE VA

TOTAL MIX SOLD BY WESTERN CANADIAN REFINERS IN 1957, IN BARRELS

1. I.O.L., Edmonton	214,630
2. McColl Frontenac, Edmonton	26,110
	240,740

Source: Tabulated from data obtained from interviews with personnel of various firms in the oil industry.

TABLE VI

DISPOSITION OF PROPANE AND BUTANE PRODUCED IN ALBERTA, IN 1957, IN BARRELS

PROPANE		
Transferred to Butane-Propane Mix		3,630
Stored		
Golden Spike	33,060	
Wizard Lake	83,690	116,750
Sales		789,020
Increase in Inventory		1,400
Miscellaneous (including losses flared, used as boiler fuel, used by producing company to repressure, for blending, in-company transfers, etc.)		300,560
		1,111,360
BUTANE		
Transferred to Butane-Propane Mix		3,780
Field and Plant Use		300
Stored		
Golden Spike	6,390	
Wizard Lake	152,800	159,190
Flared		72,000
Boiler Fuel		96,000
Sales		507,273
Miscellaneous		21,610
		860,150

Source: Tabulated from data obtained from interviews with personnel of various firms in the industry.

TABLE VII

END USES OF L.P.G. SALES IN ALBERTA, IN 1957, IN BARRELS

PROPANE		
	Domestic and Industrial Consumption	686,000
	Petrochemical Industry	44,000
	Miscible Flood (Mix)	51,000
BUTANE		
	Petrochemical Industry	371,560
	Miscible Flood (Mix)	37,860
	Blending	1,450
	Calorgas - B.C.	67,830
	Peak Shaving	28,570
MIX		
	Petrochemical Industry	240,740

Source: Tabulated from data obtained from interviews with personnel of various firms in the industry.

TABLE VIII

STORAGE FACILITIES FOR L.P.G. IN WESTERN CANADA - 1957

PROPANE

PRODUCER	LOCATION	DAILY PROD. GALLONS	STORAGE CAP. GALLONS	STORAGE IN DAYS OF PROD.
Pacific	Taylor Flats	10,000	150,000	15 days
Goliad	Pembina	84,000	840,000	10.0
B.A.	Stettler	9,000	120,000	13.3
Progas	Edmonton	6,300	72,000	11.1
B.A.	Pincher Creek	35,000	250,000	7.0
Texaco	Calmar	26,000	150,000	5.7
Royalite	T. Valley	11,000	60,000	5.4
Imperial	Devon	23,000)		
	Redwater	32,000)		
	Edmonton	87,000)	142,000	3.3

BUTANE

Distributor	2 WEEKS PEAK DEMAND	BUTANE STORAGE CAPACITY
B.C. Electric, Victoria	165,000	300,000
Vancouver Gas, Nanaimo	50,000	90,000

Source: Tabulated from data obtained from interviews with personnel of various firms in the industry.

TABLE IX

FORECAST OF POSSIBLE PRODUCTION OF PROPANE IN WESTERN CANADA FROM 1958-1962 IN THOUSANDS OF GALLONS

PROPANE	1958	1959	1960	1961	1962
BRITISH COLUMBIA					
Gas Plants					
Fort St. John	23,100	30,500	43,600	63,800	63,800
Refineries					
ST. of B.C. - Vancouver	2,000	2,000	3,000	3,000	3,000
Shell - Shelbourne	3,000	3,000	3,000	3,000	3,000
Royalite - Kamloops	300	500	500	500	500
Total	28,400	36,000	50,100	70,300	70,300
ALBERTA					
Gas Plants					
Acheson	2,420	2,680	3,560	3,960	3,960
Bonnie Glen	10,000	10,000	10,000	10,000	10,000
Stettler	7,100	7,650	9,300	10,200	10,200
Golden Spike	2,040	2,030	3,800	4,200	4,200
Elkton	*	*	4,100	4,450	4,450
Rimbey	*	*	7,800	9,100	9,100
Leduc	13,400	15,400	19,400	21,600	21,600
Nevis	*	5,600	6,000	7,000	7,000
Pembina	5,000	32,600	31,400	29,800	29,800
Pincher Creek	8,200	13,100	13,100	19,600	19,600
Redwater	5,100	5,300	6,500	6,500	6,500

Savanna Creek	*	*	*	19,000	19,000
Turner Valley	6,200	6,400	6,200	6,000	6,000
TOTAL	59,450	101,030	121,160	151,410	151,410
SASKATCHEWAN					
Gas Plants					
Alida	*	3,800	3,960	3,960	3,960
Steelman	10,000	20,000	20,000	20,000	20,000
Refineries					
B.A. Moose Jaw	2,000	2,000	2,500	2,500	2,500
Co-op - Regina	1,300	1,500	1,500	1,500	1,500
Royalite Saskatoon	500	600	600	600	600
TOTAL	13,800	29,900	28,560	28,560	28,560
MANITOBA					
Refineries					
North Star - Winnipeg	2,500	2,600	2,600	2,600	2,600
TOTAL	2,500	2,600	2,600	2,600	2,600
WESTERN CANADA - TOTAL	104,160	167,530	202,420	252,870	252,870

Source: Tabulated from data obtained from interviews with personnel of various firms in the industry.

TABLE X

FORECAST OF POSSIBLE PRODUCTION OF BUTANE IN WESTERN CANADA FROM 1958-1962 IN THOUSANDS OF GALLONS

BUTANE	1958	1959	1960	1961	1962
BRITISH COLUMBIA					
Gas Plants					
Fort St. John	15,300	20,400	29,000	44,000	44,000
Total	15,300	20,400	29,000	44,000	44,000
ALBERTA					
Gas Plants					
Acheson	1,277	1,400	1,900	2,160	2,160
Bonnie Glen	8,300	8,300	8,300	8,300	8,300
Stettler	4,350	4,600	5,200	6,100	6,100
Golden Spike	1,530	1,650	2,670	3,700	3,700
Elkton	*	*	2,170	2,420	2,420
Rimbey	*	*	8,560	9,050	9,050
Leduc	9,500	10,080	13,600	15,000	15,000
Nevis	*	5,100	5,350	6,400	6,400
Pembina	5,000	20,800	20,000	19,000	19,000
Pincher Creek	4,100	6,900	6,900	9,800	9,800
Redwater	5,000	5,250	6,250	6,250	6,250
Savanna Creek	*	*	*	9,500	9,500
Refineries					
I.O.L. - Calgary	3,800	3,800	3,800	3,800	3,800
Total	42,827	67,880	84,710	101,480	101,480
SASKATCHEWAN					
Gas Plants					
Alida	*	2,560	2,680	2,680	2,680
Steelman	6,000	12,000	12,000	12,000	12,000
Refineries					
Co-op - Regina	500	500	500	500	500
Total	6,500	15,060	15,180	15,180	15,180
WESTERN CANADA TOTAL	64,657	103,340	128,890	160,660	160,660

TABLE XI

ESTIMATED MARKET FOR L.P.G. IN WESTERN CANADA FROM 1958-1962
IN THOUSANDS OF GALLONS

	1958	1959	1960	1961	1962
PROPANE					
Production					
B.C.	28,400	36,000	50,100	70,300	70,300
Alberta	59,460	101,030	121,160	151,410	151,410
Saskatchewan	13,800	27,900	28,560	28,560	28,560
Manitoba	2,500	2,600	2,600	2,600	2,600
TOTAL	104,160	167,530	202,420	252,870	252,870
Market (10%)					
Yukon	110	120	130	140	150
Alaska	520	570	620	680	740
B.C.	13,600	14,900	16,300	17,900	19,500
Alberta	24,100	26,500	29,000	32,000	35,200
Saskatchewan	9,300	10,200	11,200	12,400	13,600
Manitoba	2,100	2,400	2,600	2,800	3,000
TOTAL	50,030	54,690	58,850	64,720	68,090
BUTANE					
Production					
B.C.	15,300	20,400	29,000	44,000	44,000
Alberta	42,827	69,080	85,910	102,680	102,680
Saskatchewan	6,500	15,060	15,180	15,180	15,180
TOTAL	64,650	104,540	130,090	161,860	161,860
Market					
B.C.	3,000	3,300	3,600	3,900	4,000
Alberta	27,500	39,000	51,000	63,000	76,500
Saskatchewan	500	500	1,000	1,500	[illegible]
Manitoba	*	*	1,000	1,500	2,000
TOTAL	31,000	42,800	56,600	69,900	84,500

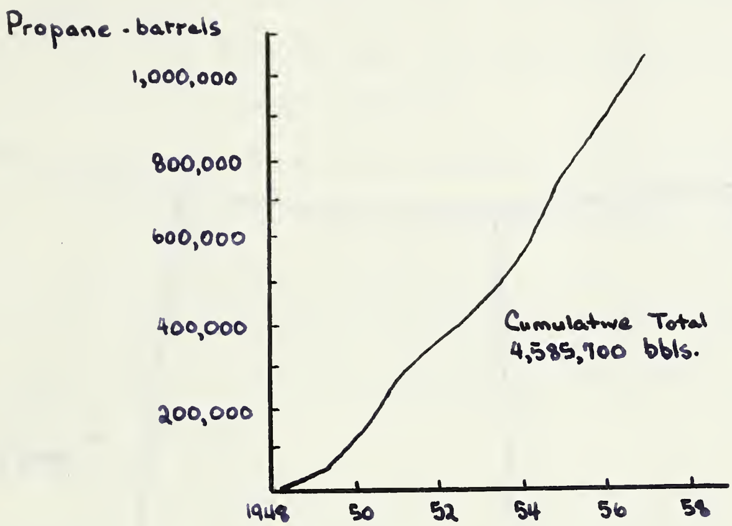
Source: Tabulated from data obtained from interviews with personnel of various firms in the industry.

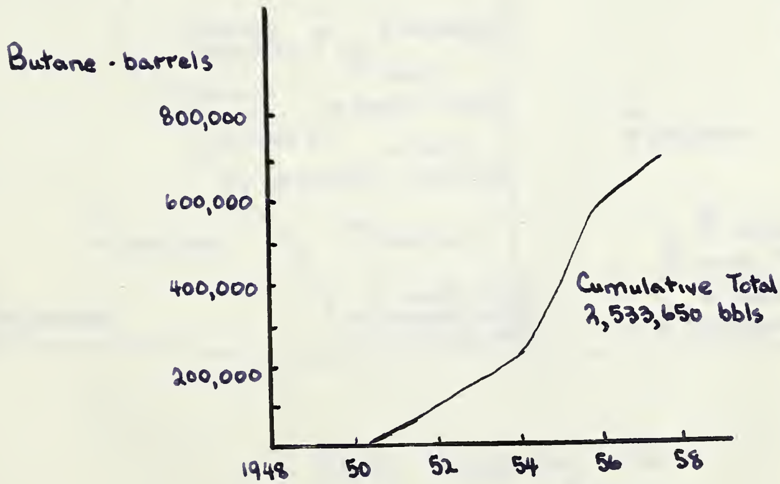
FIGURE II

PRODUCTION OF LIQUIFIED PETROLEUM

GASES IN ALBERTA DURING THE PERIOD

1948 - 1957





Source: Tabulated from data obtained from the Oil and Gas Conservation Board.

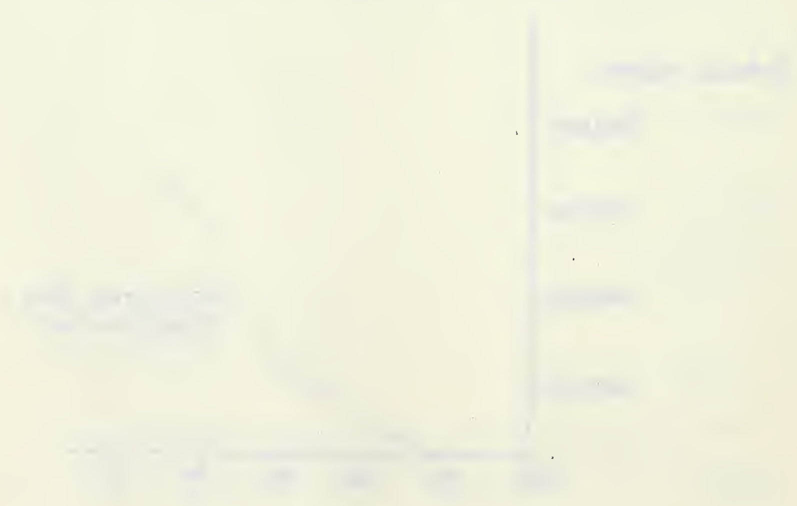
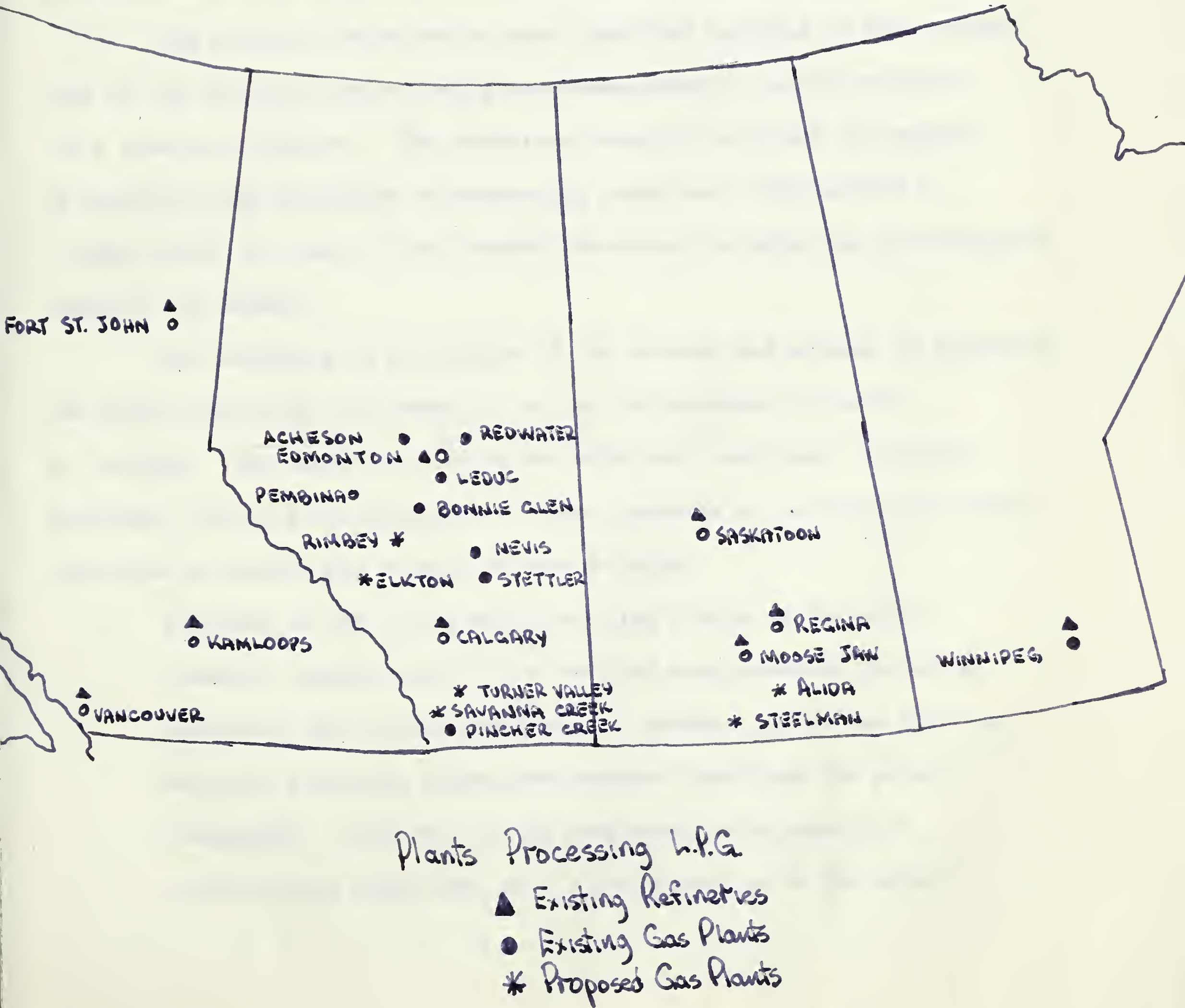


FIGURE III

LOCATION OF PLANTS AND REFINERIES PRODUCING

L.P.G. IN WESTERN CANADA



CHAPTER IV

POTENTIAL MARKETS

A. PETRO-CHEMICALS

Petroleum and natural gas have been available in quantity in North America for a century, but they did not become sources of chemicals until recently. The delay was due to the absence of demand for chemical products and lack of the engineering knowledge required to build the facilities which could separate individual hydrocarbons as pure compounds from complex mixtures.

The desire to make better motor gasoline resulted in the realization of the possibilities of using petroleum products as raw materials for a chemical industry. The petroleum industry developed the methods of analysis, the techniques of separating individual hydrocarbons on a large scale, and many of the chemical processes on which the petrochemical industry now depends.

The following is an outline of the sources and methods of producing the basic hydrocarbon raw material for the petrochemical industry.

A. Olefins: The important olefins are ethylene, propylene, butylenes, butadiene, isoprene and acetylene. These products do not exist in either petroleum or natural gas so must be manufactured.

1. Ethylene is one of the major building blocks of the petrochemical industry and is the basis of many products including synthetic fabrics and antifreeze. Natural gas is the best raw material (cracking ethane and propane) providing the price is reasonable. However, as the geographic relationship of source to the market has such a large bearing on the price,

other raw material may be more economical. Table XII shows the feed stock in the U.S. and Canada.

In 1955, the U.S.A. consumed 3 billion lbs. of ethylene, while the Canadian production was 3/4 million lbs. A steam cracker which will go into production this year (owned by I.O.L. at Sarnia) will double Canada's ethylene production using naptha and gas oil as a feed stock.

TABLE XII

SOURCES OF ETHYLENE IN THE U.S.A. AND CANADA IN 1955

	U.S.A.	CANADA
Cracking Natural Gas (Ethane and Propane)	80%	10%
Refinery Gases	10%	10%
Cracking Naptha and Oil	10%	-
Cracking Refinery LPG	-	80%

SOURCE: G.A. Purdy, Petroleum, p. 437

2. Propylene and Butylene are produced in normal refinery cracking operations. Propylene is an important raw material for polymer gasoline, acetone and detergents. Isobutylene is an important constituent of synthetic rubber, whereas n-butylene is an important source of butadiene and components for high octane gasoline.

3. Butadiene is required in great quantities for the manufacture of nylon, resins and synthetic rubber. The most widely used source is the conversion of normal butylene. Where butylene

is in short supply, butane may be converted.

Butadiene is made in Canada from Butylene in Sarnia by the Polymer Corporation, and will be made from naptha at I.O.L.'s new Sarnia refinery. All the butylene is obtained from I.O.L. Sarnia.

4. Acetylene is also a versatile "building block" and is used for plastics, synthetic rubber and solvents. Its most common source is coal and limestone. A process has recently been developed by which ethane and propane can be converted. It is not as yet developed sufficiently to determine its commercial significance.

B. Paraffins:

Any one of the paraffin series can be converted directly to petrochemicals. Propane and butane can be partially oxidized to form mixtures of aliphatic chemicals (alcohols, acids, ketones, etc.) and this is done at Canadian Chemicals Limited, Edmonton. The feed stock is obtained from natural gas and refinery LPG gases. The following products are obtained: formaldehyde, acetaldhyde, acetone, methyl alcohol and acetic acid. Acetic acid is of primary importance in the manufacture of cellulose acetate, and rayon-type fibres.

C. Polyethylene

Polyethylene is produced by C.I.L., Edmonton. The feed stock is ethane obtained from I.O.L.'s Leduc gas conservation plant.

Thus it can be seen that propane and butane have great theoretical possibilities as a feed stock for the petrochemical industry. However,

such a variety of methods have been developed that a producing plant has the choice of a number of raw materials to produce the same end product. As fixed costs are comparable regardless of the method used, the choice is usually made on a basis of the raw material costs rather than the simplest chemistry. Naturally, raw material costs depend on the location of the industry.

To be more specific, the degree to which the propane and butane reserves of Western Canada will be used for petrochemicals will depend on the location of that industry. The major factor in determining location is the relative cost of transportation of raw materials and finished goods. If the amount of raw material necessary to produce a unit amount of finished goods is large, the industry will tend to locate near the source of supply. This will also be the case when the product has a high unit value so that transportation costs form a small percentage of the total selling costs. Unfortunately, neither of these factors are generally true in the petrochemical industry, except in limited instances (i.e. polyethylene). Thus it can be concluded that the industry will locate close to the market, so that no matter how much LPG is available in Alberta, it is not likely to be processed for petrochemicals at points far distant from use. This can be verified by reference to Tables XIII, XIV and XV. LPG cannot be shipped to Eastern Canada and compete price-wise with refinery off gases. Also, in most cases it is too costly to ship the finished goods to the more concentrated markets.

Another important factor determining location is the high fixed cost which is usually necessary. Consequently, a petrochemical

plant is not normally feasible unless a large market for the output is assured. These markets do not exist in Western Canada because of the small population. As a result, an industry will be situated in densely populated areas. The desire to seek proximity to related chemical industries (to take advantage of external economies) leads to a further centralization.

There are other factors which deter expansion of the industry in Alberta: (1) shortage of trained technicians, (2) relatively high construction costs, (3) high freight rates, (4) small population, for both consumption and labor market, (5) U.S. protective tariffs which are as high as 40% on chemicals.

Thus we must conclude that the Canadian petrochemical industry will center in the East. Western LPG must therefore compete with refinery gases, something it cannot do. Freight rates subsidization is out of the question as the oil industry generally is considered the least needy, or most healthy, segment of the Western Canadian industrial economy. Thus, most petrochemical ventures in Alberta will involve a "net freight penalty."

There are several conditions which could make the picture more attractive from an Alberta standpoint:

1. A general growth in Western Canadian markets or export markets which could be reached through Western Canadian ports.
2. Development of products which require a higher quantity of hydrocarbons per pound of finished goods.

TABLE XIII

HYDROCARBON RAW MATERIAL TRANSPORTATION COST BY PIPELINE

	¢/lb/100 miles
Methane	.04
Ethane	.06
L.P.G.	.07 - .10
Crude	.015

TABLE XIV

HYDROCARBON RAW MATERIAL COSTS AT VARIOUS LOCATIONS IN ¢/lb.

	EDMONTON	VANCOUVER	WINNIPEG	TORONTO
Methane	0.3	0.55	0.6	1.1
Ethane	1.0	1.4	1.5	2.2
Propane	1.0	1.5	1.6	2.6
Butane	0.7	1.2	1.3	2.3
Pentane	1.5	-	-	-
Crude	0.9	1.0	1.0	1.1

TABLE XV

TYPICAL FINISHED PRODUCTS FREIGHT COSTS IN ¢/lb./100 MILES

EDMONTON TO	VANCOUVER	WINNIPEG	TORONTO
Fertilizer	.09	.09	.05
Polythene	.16	-	.15
Formaldehyde	.10	-	.09
Propane	.17	.15	

Source: D. Quon, "What Petrochemicals will mean to Alberta" Canadian Oil and Gas Industries, Sept. 1957, 73.

3. Special situations where raw material is available at minimum cost as a by-product of existing operations.
4. The availability of American markets by tariff reduction.
5. Shortages developing in Eastern Canadian markets. This is the reason why Polymer considered construction of a butadiene plant in Red Deer. Butylene became scarce in the East, so the company investigated the possibilities of processing Alberta butane. The plan was shelved when it was discovered that, to be comparable cost-wise with the eastern product they would have had to obtain butane at 1¢ per gal. wellhead price. The oil companies could not produce butane for this amount. However, there are possibilities that are similar, so more attractive situations may occur in the future.

A brief look at the American situation may give some idea of what could occur. The industry is much further developed because the oil resources were discovered earlier and because of the presence of a much larger market. As a result, Canada is 10 years behind the U.S. in per capita consumption of petrochemicals. Also the American industry is much more efficient because of the resultant economies to scale. The ratio of investment to value of output is 1:1 in the

U.S. whereas it is approximately 2:1 in Canada.

The more concentrated market makes the situation for LPG much more attractive in the U.S. The demand for natural gas exceeds the supply so that it is relatively expensive. On the Gulf Coast, where the petrochemical industry is centered, natural gas prices rose from 5C per M.C.F. to 13¢ per M.C.F. in 1957. Consequently, many chemical producers are switching to LPG as a raw material. The consulting firm of "Greene and Widgery" predicts that by 1960 some 56% of the ethylene manufactured on the Gulf Coast will be based on a pyrolysis of propane and butane. This will require a supply of 50,000 barrels a day of propane and butane. However, this situation is not likely to occur in Alberta as natural gas prices are not expected to increase too much for some years to come.

In conclusion, Alberta offers an impressive abundance of raw materials and lower power rates. Ontario and Quebec claim proximity to markets, less rigorous climate and available refinery off-gases, and these advantages outweigh those of Alberta. Thus the rapid expansion of the petrochemical industry in Alberta cannot be foreseen.

B. GASOLINE BLENDING

Gasoline blending is simple but determination of how much of each component to include in the blend is far from simple. Selection of the components and decisions as to their proportions in a blend are the most complex, continuing problems in a refinery. For many years butane and isobutane were used in considerable quantity. However, of late they have been replaced by other components, (mostly light naptha) which are the natural by-products of refining and have higher octane ratings. The continual increase in the octane number of motor gasolines has been the chief reason for changing composition. Thus butanes have become victims of the "octane race" and are no longer desirable as they have a low octane number, relative to other additives. Their use has been restricted to improving vapor pressures of gasoline, particularly in cold climates.

In addition, improved technology has resulted in the increasing ability of most refineries to produce large amounts of light ends. This is verified by the fact that refinery LPG production increased 19% from 1955 to 1956 to 52 million barrels, while crude production increased only 6.4%. Thus refineries in the U.S. have become self-sufficient in normal butane. In 1956, refineries produced 14.6 million barrels, while the total used for blending was only 17 million barrels.

Thus, as the low grade gasoline market has fallen, the market for light ends for use in blending has fallen. There are, however, some

possibilities which could result in the increased demand for LPG for this market.

1. If the trend to smaller cars continues, there will be an increased market for low octane, high volatile fuels.

2. Improved engine design with more extensive use of fuel injection rather than carburetion.

3. Possibility of a tight crude supply by 1970.

Thus, it is expected that over the short run, butanes used for motor gasoline will be restricted to specialized fuels. Iso-butane is an important constituent of aviation fuel. Even in these limited markets, butanes extracted from natural gas will have to compete with refinery off-gases.

C. PEAK SHAVING IN NATURAL GAS DISTRIBUTION SYSTEMS

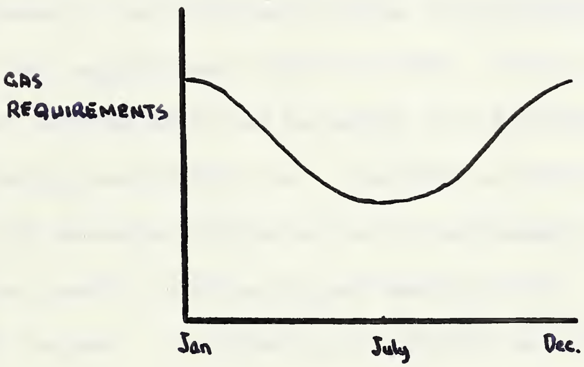
"Peak Shaving" is a term used to describe the methods used by natural gas distribution systems to supply the market when demand is at its highest. As the basic considerations are cost and efficiency, the fundamental idea is to minimize the size of the gas generating facilities and still be able to supply any possible demands on the system. Generally the public utility companies have three alternatives: (1) gas storage facilities, (2) propane-air sendout plants, or (3) oil reforming units.

The economics of peak shaving depend on the rate system and the load curve of the system. Most distributors use a two-part rate system, with a demand charge and a commodity charge. When a customer even momentarily demands a specific quantity of gas he is asking that a portion of the transmission system be reserved for his use. It is logical that he should payfor this privilege, regardless of how much total gas he uses. Thus the two-part rate is an attempt to separate the fixed costs of transmission from the operating costs of supplying the gas. Peak shaving methods depend on these rates, for it would be of no value for a strict commodity rate basis of billing.

Output policy also depends on the load curve, as a system with a 100% load factor gains nothing from peak shaving, whereas a system which has a stable demand except for a few days with very high

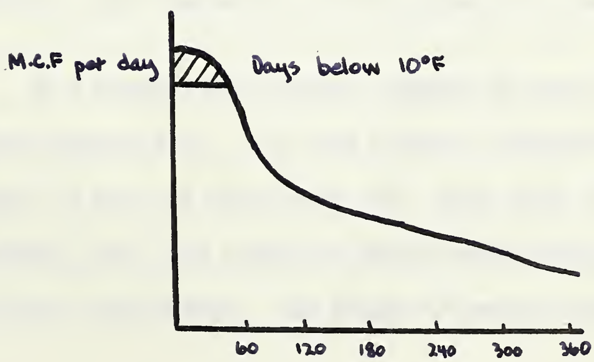
demand can spend substantial amounts to reduce this peak demand rather than build the whole system to supply the capacity needed for only a few days. Space heating is the principal contributor to a fluctuating load, and variable weather conditions are the controlling cause. From the weather pattern, a load variation curve can be plotted:

FIGURE IV



From this a load duration curve can be plotted:

FIGURE V



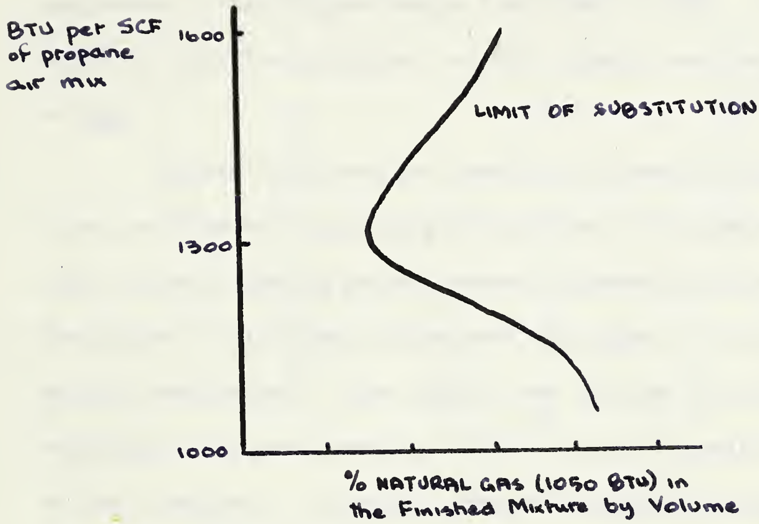
The area under the load duration curves represents the total amount demanded.

The problem is to find the method of supplying the peak gas at the lowest possible cost. The alternatives are (1) to obtain a manufactured gas which is cheaper than the cost of expanding the system to meet peak requirements, or (2) to build storage facilities for natural gas to use in peak periods. If (1) is found to be the cheaper, the additional problem of determining the most economical base load capacity must also be solved. This is an "alternative choice" problem which can be solved on a straight costing basis considering such factors as: capacity of existing equipment, capital costs of expansion, depreciation and maintenance expense, etc. There are two possible sources of peak shaving fuel: (1) reforming oil or (2) propane. In reforming, the liquid fuel is cracked thermally or catalytically into hydrocarbons of lower molecular weight. The investment cost for such a plant is always higher than the costs of a propane air plant. Thus propane is the best fuel, other than natural gas, for peak shaving. We now turn to a discussion of the possibilities and limitations of a propane-air plant.

In a natural gas system, propane has one disadvantage - non-interchangeability. To burn propane successfully on a natural gas range, it must be mixed with air. Even then it behaves differently from methane, and thus cannot be substituted 100%, due to the range of appliance adjustments. The degree of substitution depends on the

B.T.U. content of the propane air mixture and is shown in Figure VI.

FIGURE VI.



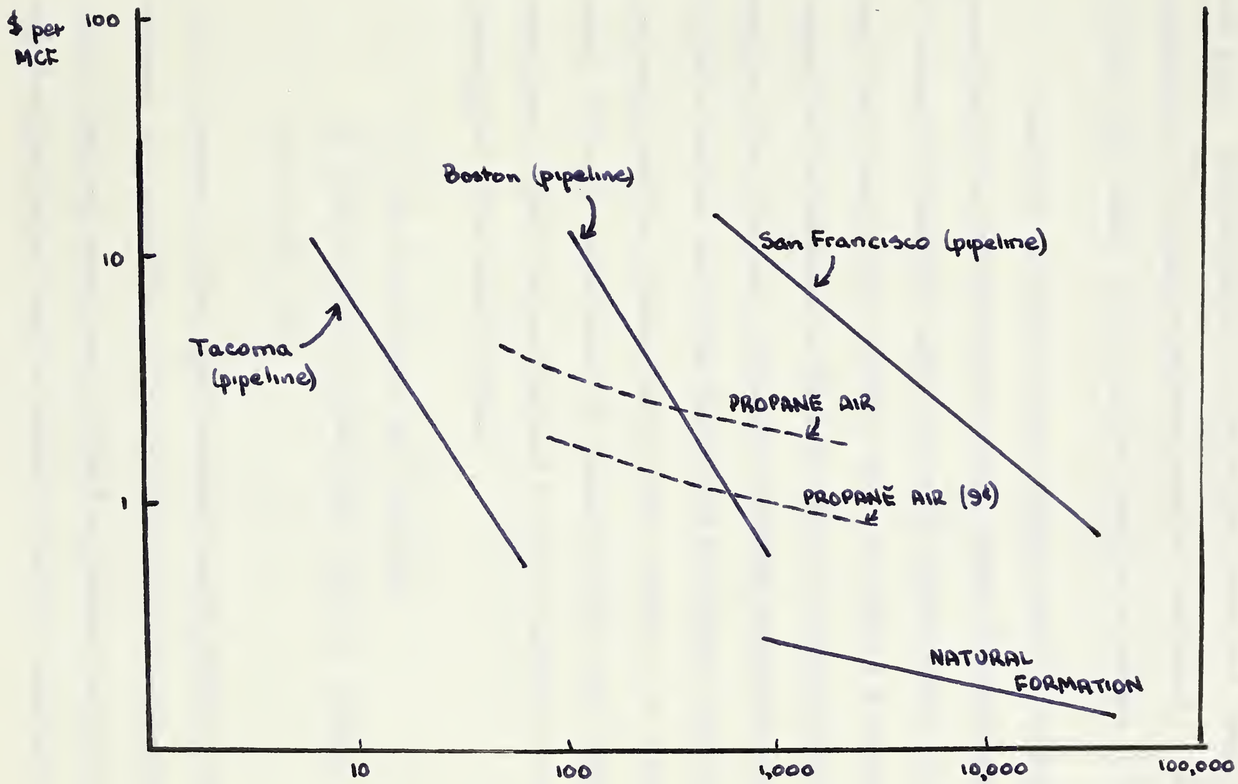
The cost of propane-air plants may be divided into two parts - the storage facilities and the compressor and mixing plant. Storage costs range from 60¢ to 90¢ per gallon of capacity, if tanks are used. On the basis of equivalent 1000 B.T.U. gas, this means a cost of \$6.50 to \$9.50 per M.C.F. Storage in manually excavated caves has been studied and indications are that it would be economical for anything over 250,000 gallon capacity, and costs range from 20¢ to 60¢ per gallon of propane stored. In some areas, salt caverns are available and costs could be as low as 4.5¢ per gallon of capacity

if in excess of 2,000,000 gallons. Another possibility is the use of depleted gas reservoirs, where costs range from 15¢ to 25¢ per M.C.F. capacity. The cost of compressors and mixing plants can be reduced to a unit cost per brake horsepower when air must be compressed. This figure ranges from $300 to $600. The cost of L.N.G. is less than propane, but the storage costs are about twice as high.

Figure VII shows the results of research conducted by the Stone and Webster Engineering Corporation to determine the relative costs of peak shaving gas in several representative American markets. The figure of 11.7¢ per gallon cost of propane is realistic for the markets considered. From this it can be seen that Tacoma cannot use propane for peak shaving, whereas it is a possibility in Boston or San Francisco. The curve labeled "natural formation" is the cost of storing natural gas in a depleted reservoir. It is quite evident, that such a formation, if it can be found, provides the most economical storage.

The general conclusion is that propane or liquified natural gas is economical only when relatively small amounts are required for peak shaving, with underground storage of natural gas indicated for the large operation. The choice between liquified natural gas and propane, depends to a considerable extent upon the price of propane.

In the overall picture there are several other points worthy of consideration in determining the choice of methods. Firstly, the



ANNUAL PEAK SHAVING GAS - MILLIONS OF CUBIC FEET

Assume: Propane costs 11.7¢ per American gallon.

Source: Stone and Webster Engineering Corp., Peak Shaving for Natural Gas Distribution Systems, (San Francisco, 1953).

rate of load growth is important. If the load is growing rapidly, there is more use for peak fuel because the peaks become greater each year. Also, estimates of future fuel costs and reserves and availability of storage reservoirs must be considered. An attempt to apply this theory to the Western Canadian situation follows.

Recently, Canadian Western Natural Gas Co., of Calgary, investigated the possibility of using propane for peak shaving. At present the company's major source of natural gas is the Jumping Pound field owned mainly by Shell Oil. As this is a sour gas, the company had to guarantee a 70% load factor to induce Shell to construct the relatively expensive scrubbing equipment necessary. The other sources are Turner Valley and Bow Island, with the latter also being used for storage during slack seasons. In a recent survey of future requirements it became apparent that additional quantities of fuel for peak periods would be required. The company investigated three possibilities:

(1) Draw from Alberta Gas Trunkline

(2) Draw from the Carbon field, north of Calgary

(3) Use of L.P.G.

Because of the highly seasonal demand, caused by temperature extremes, the quantities of fuel needed for peak shaving are relatively large. Thus the actual cost of the fuel becomes the most important consideration rather than the amount of capital necessary to provide

facilities. Figure VIII shows that the price of propane greatly exceeds that of natural gas when the two are compared on a B.T.U. basis. Even if it is realized that in the future, the price of LPG in comparison to gas is liable to swing in the favour of the former, the discrepancy is too great to make propane competitive. This, coupled with the fact that the capital investment required to bring the product to market is less for gas than it is for propane, is sufficient reason for not giving any more than passing attention to the possibilities for using LPG. As the size of the market grows, even though the relative amounts necessary for peaking remain constant, the actual quantities increase so that the peak shaving operation is going to require even a greater volume of fuel than at present. Thus the long term picture also seems to exclude the possibilities of using LPG.

Consequently the company decided to use natural gas for peak loads, with the Carbon field as the source. The Trunk Line possibility was ruled out because the price would be too high as (1) suppliers would be required to build large stand-by storage facilities and (2) the capacity of the Bow Island pipeline would have to be increased. It would be even more difficult for propane to enter the picture in Edmonton. The Viking-Kinsella field, long the base load field, is now insufficient to supply the growing demand and will be replaced by Pembina. However, Viking-Kinsella has ideal storage facilities so will become the source of peaking gas.

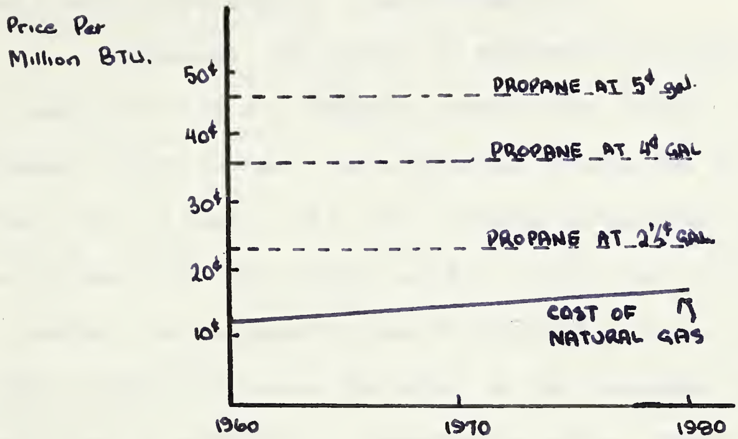
Propane is also choked out of the smaller municipalities, in which it should be theoretically adaptable, by the simple fact that the availability of propane can only be accompanied by the co-existence of a large supply of natural gas, which is always much cheaper.

An analysis of the Edmonton market was made to determine whether there was any possibility of using LPG on a continuous basis, i.e. inject a fixed quantity of propane-air mix into the system all year round. In Edmonton, the retail price of gas varies from 34¢ per M.C.F. for domestic consumption to 13¢ per M.C.F. for large industrial users (such as the Imperial Oil Refinery). The company anticipates a 45% rate increase in 1959, with 68% of this increase being attributable to increases in the cost of natural gas. The company pays anywhere from 2¢ per M.C.F. in Viking to 13¢ in newly negotiated contracts for Pembina gas.

An estimate of future costs of gas was made, using the proposed contract between Northwestern Utilities and Alberta Southern as a basis. Alberta Southern is seeking an export permit, which, if granted, will result in their purchasing the transmission line from Pembina to Edmonton from Northwestern Utilities and supplying Edmonton's requirements free of transportation costs and exporting the surplus. On the basis of the proposed contract between the companies, the following is an estimate of future gas prices. In the opinion of the officials of the company, this represents a conservative picture of future costs of natural gas:

FIGURE VIII

COMPARISON OF THE COSTS OF PROPANE AND NATURAL GAS ON A B.T.U. BASIS



The preceding graph is a result of the following computations:

1. Estimated natural gas prices: (wellhead)

   a. 1960 - 12¢ per MCF of 1000 BTU gas

   b. 1980 - 18¢ " " " " " "

2. Propane Prices:

   a. 109,700 BTU per imperial gallon

   b. Propane at 5¢ per gallon

   Price per 1,000,000 BTU $= \frac{5 \times 1,000,000}{109,700} = 45.6¢$

   c. Propane at 4¢ per gallon

   Price per 1,000,000 BTU $= \frac{4 \times 1,000,000}{109,700} = 36.5¢$

A reliable oil company executive estimates that the minimum price at which propane could be sold without sustaining a considerable loss is $2\frac{1}{2}$-3¢ per gallon. Thus, the cost of production of propane is too high for a gas utility company to use it economically.

If, however, the problem is approached from the standpoint of conservation of our resources, rather than trying to obtain the cheapest source of fuel, quite different conclusions can be drawn. Grant, for the moment, that the following assumptions are realistic in the long run: (1) natural gas has a value (say 12¢ per M.C.F.) on the market, and any quantity can be absorbed by export and (2) the supply of LPG will exceed the market as the geographic market is restricted by prohibitive transportation costs. Under these circumstances the problem resolves itself into a choice between using natural gas at 12¢ per million BTU and flaring LPG or exporting the natural gas and using the higher cost fuel. Thus, as long as the price of LPG is less than twice the cost of natural gas it is more economical from a provincial conservation viewpoint to use the more expensive fuel and sell the natural gas to export markets. The validity of this statement is contingent on (1) the validity of the original assumptions, and (2) realization of the fact that the ratio of 2:1 will have to be reduced by an amount corresponding to any additional investment necessary to adapt the system to the use of LPG. An example may help in understanding this situation.

Suppose that the propane resources of the Pembina field were fed into the Northwestern Utilities system for Edmonton in 1960, and

suppose that the following estimates are within a range of realism:

1. Propane output - Pembina field - 32,000,000 gallons.
2. Edmonton's annual requirement of gas - 40×10^9 cu. ft.

Thus, on a BTU comparison, the propane resources amount to 8.75% of the total demand. Now assume a wellhead price of propane in Pembina of 2½¢ per gallon, so that if all the propane was sold to Northwestern Utilities the total cost to the distributor would be \$800,000 (.025 x 32,000,000). The use of this gas results in an additional income from exporting gas of \$420,000 (3,500,000 MCF x 12¢) or a net cost of \$380,000 and a saving of \$40,000 (420,000 - 380,000).

If Figure VIII can be considered as realistic, this use of propane would absorb about 1/3 of the estimated surplus in 1960, and would have a stabilizing effect on the industry. This type of policy would undoubtedly encounter objection from the consumer unless the proceeds of the exported gas were applied against the cost of servicing the Edmonton market. In spite of the administrative difficulties, it would certainly assist the long run development of the whole petroleum industry as any policy which restricts waste is beneficial.

At the present time, this suggestion cannot be expected to gain too much favor. However, once export markets for gas become plentiful, it may become a worthwhile method of helping to balance temporary surpluses of LPG against deficiencies of natural gas.

D. FARM AND RURAL USE

Historically the largest market for LPG has been as a fuel on farms and in rural communities. In the U.S.A. in 1957, farm customers accounted for 44% of the gallonage, 47% of the equipment purchases, 45% of the dollar sales and 42% of the number of customers of the LPG industry. The farmer has a variety of possibilities in determining his fuel requirements. Coal, wood, natural gas, stove oil, electricity and LPG compete for space and spot heating while for combustion engines and equipment he may use diesel fuel, gasoline or LPG. His choice will be a result of considering such factors as relative cost, efficiency, and convenience. As costs vary greatly between regions, no generalizations can be made, so each area must be considered separately.

There is an unlimited variety of possible uses for LPG on the farm, the most common of which are central heating, stoves, refrigerators, air conditioners, trucks, tractors, combines, irrigation pumps, grain dryers, insect or weed killers. However, these areas cannot be exploited unless the price is competitive with other fuels. The following table gives the wholesale price per 1,000,000 B.T.U. of the various fuels in Edmonton. Edmonton was chosen because it is centred in the source area of most of the products and transportation costs would have a minimal effect.

COST PER 1,000,000 B.T.U.

1. Diesel		$1.01
2. Heating Oil		.87
3. Intermediate Heating Oil		.73
4. Bunker Fuel	(Heavy)	.29
	(Light)	.40
5. Propane		.55
6. Coal		.34

For space and spot heating, gas or electric equipment is much more convenient, and in spite of their higher cost will always be preferred over coal or wood. Coal and wood are the most popular fuel in poorer areas. In addition, as the immediate costs necessary to install more modern equipment are quite high, coal burning equipment is retained in some wealthy communities. However, there is no questioning the fact that propane equipment is much cleaner and requires much less effort. Natural gas pipelines are normally uneconomical for sparsely populated areas so propane, transported in cylinders, is the most economical gaseous fuel and is an ideal source of concentrated heat to which the accurate control of gaseous fuels can be applied. In spite of being more expensive than competing heating fuels, propane would capture more of the rural market if the industry were more aggresive. The most apparent method is to service farms completely, rather than try to sell to more farms who burn propane for only a few uses. By concentrating the market in this manner, distribution and storage costs

would be lessened and this saving could be passed on to make the fuel more competitive. Probably, the more important selling point is that any additional costs incurred by switching from cheaper heating fuel would be balanced by decreased fuel costs for tractors and other equipment. The only people trying to effect this change are the salesmen of the individual distributing firms. An increased degree of industry wide co-operation would certainly make sales programs more effective. The truth of this fact is born out by a study made by Imperial Oil Ltd. in 1955, to determine the relationship between the actual and the potential rural market. They approached the problem from three aspects:

1. Determining the rural per capital consumption of propane and projecting it on to an estimate of population increase.
2. Determining the consumption per rural household and estimating the increase in households together with forecasting increases in volume used per household because of increased use as a heating fuel.
3. Projection of anticipated sales.

The average of these estimates revealed the following estimate of the market for propane for rural consumption in thousands of gallons:

TABLE XVI

	1956	1957	1958	1959	1960
Manitoba	666	790	915	1,067	1,254
Saskatchewan	5,591	6,756	7,939	9,405	11,145
Alberta	17,519	20,559	23,528	27,049	31,048
B.C.	4,862	5,672	6,154	7,032	8,048
TOTAL	28,638	33,277	38,536	44,553	51,495

Source: Imperial Oil Limited.

Next they estimated the potential market for rural consumption on the following assumptions:

1. Lighting	5% of occupied dwellings using 25 gallons of propane/year					
2. Refrigeration	10% " " "	"	100	"	" "
3. Cooking	25% " " "	"	120	"	" "
4. Hot Water	25% " " "	"	120	"	" "
5. Heating Fuel	25% " " "	"	1300	"	" "
6. Tractors	10% " " "	"	1800	"	" "

The resulting figures for potential market are:

TABLE XVII

POTENTIAL DOMESTIC AND TRACTOR MARKET FOR PROPANE IN THOUSAND GALLONS

	1956	1957	1958	1959	1960
Manitoba	45,627	46,184	46,642	47,153	47,746
Saskatchewan	944	86,682	87,577	88,405	89,087
Alberta	70,242	71,159	72,119	73,003	73,888
B.C.	52,818	53,934	55,000	55,730	56,248
TOTAL	254,631	257,959	261,338	254,291	266,969

Thus, the estimated actual market as a percentage of the potential is:

	1956	1957	1958	1959	1960
Manitoba	1.5	1.7	2.0	2.3	2.6
Saskatchewan	6.5	7.8	9.0	10.6	12.7
Alberta	24.9	28.8	32.5	37.0	42.0
B.C.	9.2	10.5	11.3	12.6	14.3

This analysis is open to criticism; particularly justification of using the same assumptions for all provinces without regard for varying

costs. Nevertheless, it can be considered sufficiently realistic for our purpose. Several conclusions can be drawn: (1) There is considerable opportunity for propane distributors in Manitoba and Saskatchewan when pipeline facilities warrant development of local gas fields. When this happens, propane can be obtained locally rather than being imported from Alberta so that costs will be competitive with other fuels. (2) The largest potential market is for space heating where the cost of propane is least competitive . As mentioned previously, this market can best be secured by a "complete servicing program" which in turn requires industry wide co-ordination to be effective. (3) There is considerable scope for expansion.

On the other hand, there are several limiting factors to the increasing use of LPG for farm consumption. Because of the geographic limitations where LPG is competitive price-wise with other fuels, the market is restricted. Hence there is a reluctance on the part of manufacturers of appliances to develop and promote equipment using LPG. Without large output, unit costs are high and often restrictive. In addition, seasonal demand makes large scale transportation and distribution investment un economical. It is difficult to balance the effects of seasonality with other users, as it is unlikely that they would locate in predominantly rural areas.

We can therefore conclude that the rural domestic market offers considerable scope for absorbing some of the expected surplus for propane in Western Canada. There are many problems to overcome, but with proper organization and aggressive merchandising the market can be secured.

E. INTERNAL COMBUSTION ENGINES

Considerable research has been carried out in an effort to develop automotive engines which use propane as a fuel. The result has been the designing of equipment which can be technically and theoretically more efficient than gasoline or diesel. In engines specifically designed for the higher compression ratios particularly suited for butane (8 to 1) and propane (12 to 1), the gases provide a means of raising thermal efficiency (i.e. a greater return of useful energy for the same amount of fuel). LPG has better anti-detonating properties, which tend to give smooth, powerful and efficient operation without the ill effects on the engine consequent on the use of lower octane fuels. In addition, additives (tetraethyl, lead, etc.) are not required to combat detonation so that the life of rings and valves is not adversely affected. Since the engine is supplied with a mixture of dry gas and air, the fuel burns completely and cleanly without carbon residue. Maintenance costs are further reduced by the fact that the fuel enters the carburetor in a dry vapor state so that the oil remains cleaner and does not have to be changed as often. Also, there are several minor advantages of LPG engines which make them attractive: no exhaust odors, good fuel economy for part loads and absence of a fuel pump.

The engines themselves are more complicated and several modifications are required to convert standard gasoline engines to LPG use. Compression ratios should be increased, and a larger intake manifold, pressurized fuel tanks, pressure regulator, and filter must be

added. However, these additional fixed costs can be more than balanced by savings in fuel and maintenance costs under favorable conditions.

It is not, however, a one-way street, as LPG engines have some inherent disadvantages. They offer less work output (horsepower /hour) per gallon than gasoline or diesel equipment. Because of the bulky, pressurized tanks, storage and re-fuelling is cumbersome. Also the high vapor pressure increases the possiblity of leakage and consequent explosion, so they must be handled carefully. LPG equipment is hard to start in cold weather, because vapor pressure is difficult to build up. Consequently, the engine's electrical system must be kept in good condition.

A factor which will have a profound effect on the future of LPG engines is the policy adopted by equipment manufacturers. They are faced with the choice of making engines versatile so they can take advantage of regional differences in fuel costs and changes in prices over time, yet making the machine specialized enough to permit technical advantages for a particular fuel. Because propane is not competitive in the larger consuming eastern industrial areas the tendency has been to seek competitive advantage by specializing for gasoline or diesel. Whether or not pressure to change this policy by western users would have any effect is open to question. However, if this were accompanied by assurances by eastern refineries that they would produce more LPG at a reasonable price, the manufacturers would probably be willing to produce more versatile equipment. The problem resolves itself to this:

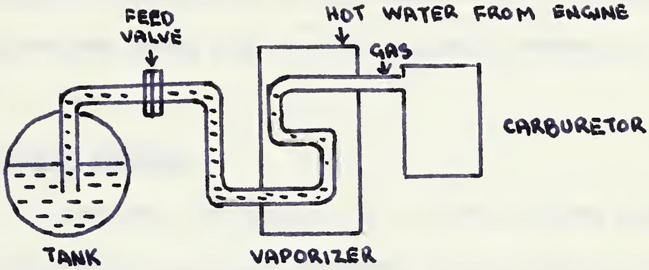
is it more advantageous from a Western Canadian point of view for eastern refineries to restrict or promote LPG production? If they restrict, there is a possibility that the Western Canadian product could be shipped to eastern markets. If they expand production, they increase the entire market and propane equipment would be more available. The latter would seem to afford the best possibility for expansion of the industry in Western Canada. Nevertheless, the LPG industry finds that the price of its product is set at the discretion of major national oil companies, who in turn must consider the whole picture - Western production, eastern refining, and foreign holding, etc., before committing themselves in any particular segment. This will be discussed under separate heading.

THE BASIC PRINCIPLES OF L.P.G. CARBURETION

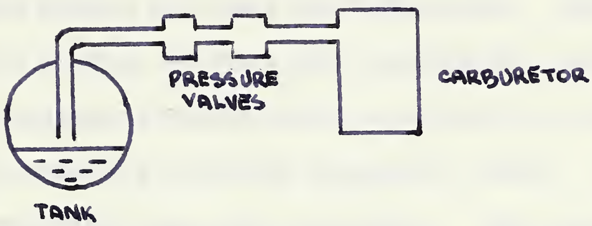
There are two types of carburetion systems - liquid withdrawal, and vapor withdrawal - neither of which requires a fuel pump as the vapor pressure insures flow.

FIGURE IX

LIQUID WITHDRAWAL



VAPOR WITHDRAWAL



The former can use either propane or butane; the latter is unsuitable for engines in cold weather because LPG has too high a boiling point and loses too much heat from evaporation so requires a substantial amount of heat around the tank. Fuel consumption varies inversely with the vapor temperature. Thus it is generally necessary to start and warm up the engine on vapor withdrawal from the supply tank

until engine temperature is sufficiently high to offset the refrigerating effect of the fuel vaporization. This represents an inconvenience for the operator as he must start on vapor by opening the vapor withdrawal valve and then change over to the liquid withdrawal valve when the engine temperature is high enough. This problem becomes more acute in the cold winters experienced in this region.

We now turn to a discussion of the possibilities of propane and butane in the various types and uses of internal combustion engines.

POSSIBILITY FOR DIESEL ENGINES

Propane, as it enters the engine, is a clean uniform vapor with an octane rating which is in the category of the finest aviation fuel. When utilized in an engine of sufficient strength and rigidity to accommodate compression ratios commensurate with this octane value, its fuel efficiency factors are among the highest know. Gasoline engines will run on propane, but only after considerable conversion costs because the ordinary gasoline engine is not built to withstand the high pressures resulting from high compression ratios. A diesel, however, is an ideal basic engine for conversion. The compression ratio for propane is 1/3 less than that for which the average diesel is built, so that long engine life is assured. Thus, because of the stronger original engine, wear is reduced by as much as 25%, maintenance costs by 20%, and according to figures released by the Cyclo-dyne Corporation in the United States, power can be increased as much as 50%, depending on

the design of the original engines. Thus, there is a favourable "fuel cost per mile" ratio for propane. The conclusion is that it is cheaper to convert a diesel engine to propane than it is to construct a propane engine. The conversion costs are no more than a major overhaul. The limiting factor in Western Canada is the supply of diesel engines with sufficient wear to warrant additional investment.

Another possibility is to inject a propane-air mix, instead of straight air, into a standard diesel engine. This type of thinking is still in the experimental stage, but indications are that power output is increased without increasing fuel costs.

POSSIBILITIES AS TRACTOR FUEL

This is a market which LPG should be able to capture if the only considerations were of a technical and theoretical nature. The Kansas State College has undertaken an extensive research program to determine the advantages and disadvantages of the various fuels-propane, diesel and gasoline - which can be used for tractors. From a cost and an efficiency standpoint they reached the following conclusions: (1) Propane is superior to diesel if used less than 1500 hours per year, and diesel and propane are the same price and (2) propane is superior to gasoline if used more than 500 hours per year and gasoline prices are 150% of propane prices. As the wholesale prices of the various fuels in Edmonton are: propane - 6¢ per gallon, diesel - 16¢ per gallon and gasoline - 22¢ per gallon, propane should be the major fuel for this market.

In actual fact, of the 500,000 farm tractors which are in operation in Western Canada less than ¼ of 1% use propane. There

are several reasons for this phenomenon, probably the most important of which is the attitude of the major oil companies toward L.P.G. generally. The whole oil industry is controlled by a small number of very large integrated companies who produce, refine and distribute their products nationally. Consequently, any efforts to promote the use of propane would, if successful, result in the decreased use of their other products. In effect, a company would be competing with itself, so that L.P.G. is the forgotten product. If we could visualize the industry as having each firm concerned with one product only - diesel, gasoline or propane - one cannot help but feel that propane would have more uses than it does at present. In short, no large, financially secure company is very concerned about increasing the market for L.P.G. in areas where it competes with gasoline or diesel. Farm tractors fall into this category.

There are other more specific reasons why propane is not used more extensively for tractor fuel in Western Canada. Because L.P.G. is a relatively young and undeveloped industry there has been considerable uncertainty regarding uniform prices and a lack of assurance about a continuing supply. In addition, there is a shortage of both experiences service personnel and distribution facilities. The average farmer, being of a conservative nature, would rather use a product of which he is sure than use a newer fuel, of which he has imperfect knowledge, even if the former is more expensive. Thus farmers have continued to use tractors burning purple gasoline rather

than invest in propane-driven engines. The first step necessary to counteract this tendency is research to eliminate the operational deficiencies of the propane engine. The Research Council of Alberta is at the present time attempting to develop an engine with a simplified carburetion design which still maintains the pressure regulation and control mechanism so necessary for efficient operation of the engine. Preliminary work has resulted in the following conclusions:

1. Methods should be devised for prevention of hazards due to leakage from high pressure lines.
2. New techniques for vaporization of fuel are required. Present methods vary too much with the temperature and demands of the engine and with outside air temperature.

"It is suggested that research be carried out on a pressure heat exchanger. If under a pressure higher than that supplied by the L.P.G. tank, a certain quantity of heat can be added by a liquid to liquid heat exchanger, and this quantity is sufficient under normal circumstances to volatalize the fuel when it is released to atmosphere pressure, then such a system need have only a short connection to the main tank, of a type not likely to cause leaks and its low pressure side could supply gas to a conventional L.P.G. carburetor by means of a simple hose system under low pressure".[1]

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1. H. A. Spencer, Liquid Petroleum Gas Research, Research Council of Alberta, 1958, unpublished.

If further research of this nature proves satisfactory, the probable result would be an increase in the types of engines using L.P.G. There is a potential market for stationery engines, industrial and road equipment, and bus or truck fleets with fixed points of origin and destination. This market is of particular importance because it would reduce the seasonal variations of demand. The Fuel Oil Transaction Act makes propane less attractive to prospective Alberta consumers. Under this act, there is a 10¢ gallon tax on propane when used as a motor fuel on Alberta highways, with the exception of units employed solely for the movement of L.P.G.

POSSIBILITIES FOR TRANSIT BUSES

The use of propane engines for urban transit buses has not found wide acceptance. Nevertheless when they have been used, results have been promising. A paper written by the Technical Information of the Federal Government suggested that for bus operation, based on a cost of $250 to $300 per vehicle for conversion, and $12,000 for installation of storage facilities, the operator must be able to buy propane for 3/4 the price of gasoline to break even. In spite of this, Edmonton is the only Canadian city which uses propane buses.

The E.T.S. uses electric, diesel, gasoline and propane buses. Because of the deep river valley, propane is excluded from trans-river routes because it cannot supply the high power necessary for steep grades. However, it has been used with great success on level routes. Edmonton's propane bus engines are as clean and wear free after 150,000 miles as the normal gasoline engines are at 50,000 miles.

Records have shown that by operating a controlled fleet of these buses the down time is very low and availability approaches 95%. However, close control of the carburetion and ignition systems is essential so that trained mechanics must be retained.

It is not technical efficiencies which limit the use of propane buses in Edmonton, but shortage of standard engines or equipment which can be converted to L.P.G. use. Thus we run into the ever present problem of reluctance on the part of equipment manufacturers to produce propane burning engines. The obvious solution is to persuade other cities to demand this type of production. Failure to do so can be attributed to three factors: (1) lack of coordination of propane distributors in various areas, (2) the prevelance of civil administrations which control both transit and electrical systems, and (3) the fact that once a particular fuel is chosen the high initial cost of equipment make it uneconomical to change before present equipment is worn out.

F. MISCIBLE FLOOD

Conventional methods of producing crude oil generally leave in the depleted reservoir one to three barrels of oil for every barrel brought to the surface. As long as operators have to leave pools which still contain oil, efforts will be continued to increase recoverability. The unrecoverable oil in petroleum reservoirs is largely trapped by capillarity. Since flushing with a solvent is exceedingly effective in combatting this type of loss much effort in this direction has been made in recent years. L.P.G. has been suggested as a relatively inexpensive, abundant and easily recoverable solvent for crude oil. Unlike water, L.P.G. can simply dissolve the oil out of the reservoir rock, yet it still has the desirable liquid characteristic. In other words, with water flooding, water comes along and pushes the oil out of the way in a pistonlike manner. Isolated pockets of oil are left behind the front as capillary forces cause retention of the oil in the pores of the rock. With solvent extraction, the displacement proceeds as in the case of a water flood except that there is no sharp discontinuity between the two fluids. There is no interface similar to that found in unmiscible fluid displacement. Instead, there is a transition zone, or a region where the solvent and the oil mix. The flow rate must be slow enough to allow the solvent to mix with the oil yet fast enough so that the front will not spread out too far by diffusion.

Probably the biggest drawback to L.P.G. flooding, and no doubt a strong reason for its slow adoption by the industry is the high

cost. In general it is uneconomical to inject a volume of L.P.G. into the reservoir to remove a like volume of oil.

It is possible to remove part of this economic disadvantage by recovering most of the solvent and using it again. However, generally speaking, this involves an abnormally large supply of L.P.G., ties it up for a long time in the reservoir, and requires large expenditures for processing equipment. Probably a more economical method is to use a minimum amount of L.P.G. and two modifications of solvent flushing have been developed with this in mind: (1) a gas driven solvent bank, and (2) enriched gas injection.

In the first method a small bank of L.P.G. at the input wells in driven by gas through the reservoir to the producing wells. Initially, gas is injected into the reservoir in sufficient quantity to keep the propane (or butane) in a liquid state. The quantity necessary is determined by depth, (temperatures increase 1°F, for each 70 feet down) the existing pressure, the porosity of the rock and the size and nature of the reservoir. Then the bank of L.P.G. is injected and flows out in all directions from the input well, building up an oil bank ahead of it. When all the propane is in the reservoir, gas is injected to move the propane and the oil to the producing wells. The L.P.G. will be moved through the reservoir both as a liquid and as a vapor where it mixes with the chasing gas.

In enriched gas injection, substantial quantities of L.P.G. are added directly to the gas stream and the wet gas is injected as a driving fluid. The L.P.G. in the gas stream condenses and dissolves in the gas stream. This reduces the viscosity and swells the oil in

the region. Thus, an oil bank rich in L.P.G. is built up ahead of the gas front very similar to the solvent bank in the other system.

Both these methods have resulted in increased oil recovery. A decision to use either one of them in a particular situation must be based on local conditions, so it is difficult to make any general statement regarding their economic significance. In the U.S. the oil industry is drilling more and deeper wells and making fewer big discoveries. Nevertheless, the demand for oil increases each year. It is natural that oil companies, faced with this situation, concentrate on recovering more of the oil existing in known crude reservoirs. Consequently, there is considerable scope for miscible flood operations.

Secondary recovery is a theoretical possibility for any pool but it has definite practical limitations. From a technical viewpoint Canada has profited by American experience in establishing more efficient primary recovery techniques. As a result, the only fields which are liable to have inefficient ultimate recovery are those which have a dissolved gas drive, and excess production causes too great a loss of pressure. In this case secondary recovery methods are effective for maintaining pressure, if there is continuity in structure between injection and producing wells. In Alberta these conditions (dissolved gas drive and continuity of structure) exist in only a limited number of pools, ie: Pembina, Golden Spike.

Where they do exist and there is scope for secondary recovery, the operator has a choice between a gas injection and water injection and this is in turn, dependent on market considerations.

Water injection is cheaper, but less efficient than gas or L.P.G. injection. Thus to warrant the choice of some type of gas drive, there must be ample demand to absorb the increased production and this is hardly the case in Alberta. At the present time, most wells are not permitted to produce much in excess of their economic allowable so there is little incentive to try to increase output capacity. This situation is liable to continue until markets for our crude oil are expanded either to Montreal or to the U.S. When, and if this occurs the use of L.P.G. for miscible flood operation will be expanded but it is doubtful if it will be used in sufficient quantities to counteract the surpluses which are forecasted.

At the present time, miscible flood operations in Alberta are on a "pilot plant" basis with most interest being shown in the Pembina field. There, pressure dropped as extraction continued and because there were many marginal wells, portions of the field were unitized so that some wells were converted to injection, and their allowables transferred to the production well. In 1957, Canadian Bishop and McColl Frontenac jointly used 73,000 barrels of L.P.G. and Mobiloil used 7,500 barrels for secondary crude recovery. Preliminary tests indicate that the best mix is 50% propane and 50% butane followed by natural gas. The maximum propane to butane ratio is 3:1. Mobiloil originally planned to expand their operation to 1.5 million barrels of L.P.G. in 1958, purchasing the gas at low summer prices and renting storage from Goliad. The depressed state of the industry curtailed this program.

In a special case, Texaco successfully petitioned the Conservation Board to allow the L.P.G. volume injected to be added to the maximum permissable rate for determining allowables. If this is a

precedent, it will supply an incentive for other companies to do the same when maximum permissable rates become significant.

In conclusion, it is felt that miscible flood will only be a significant user of L.P.G. in the Pembina field and even there it cannot compete favorably with water flooding until the demand for crude oil increases to a considerable extent.

CHAPTER V

TRANSPORTATION AND POSSIBILITY OF EXPORT

In the U.S. the supply-demand equilibrium is improving because of the increasing number of pipelines and the use of underground storage to counteract the sharp seasonal differences. The bulk of L.P.G. pipeline distribution is through products pipelines built or converted to handle products with the specific gravity of L.P.G. There are four methods of L.P.G. pipeline transportation: (1) Batching L.P.G. through products pipelines, (2) lines handling L.P.G. mixed with natural gas liquids (3) pipelines handling propane - ethane mixtures, and (4) batching L.P.G. through crude oil pipelines.

The largest L.P.G. pipelines in the U.S. are from the interior of Texas to the gulf coast. There are three with a total capacity of 100,000 bbls. a day built to supply the huge refining and petrochemical industries in the Houston area. In addition there are lines to Denver, St. Louis and Chicago, and the Atlantic Seaboard. An indication of the effect this has is the fact that U.S. eastern markets pay about 13 - 13½¢ per gallon for L.P.G., of which 7.5¢ is transportation costs.

Pipelines require large scale storage facilities because the relatively constant flow does not usually correspond with demand. Underground storage is far cheaper than above-ground tanks for the large quantities involved. Several types-salt caverns, mines, cavities, or depleted oil reservoirs have been used with varying success. The total facilities amounted to 33.3 million barrels capacity at the end

of 1957, of which 23.3 million was in West Texas.

The following table shows the percentage of total gallonage transported by the various carriers in the U.S.A.

TABLE XVIII

PERCENTAGE OF TOTAL GALLONAGE OF L.P.G. TRANSPORTED BY VARIOUS CARRIERS IN THE U.S.A.

	1956	1952
TRUCKS	44.5	33.
RAIL TANK CARS	41.8	56.4
PIPELINES	7.4	2.2
TANKERS	1.3	1.3

Source:L.P. Gas; April 1958, 47.

In January 1958, there were 21,880 L.P.G. tank cars and 12,200 which were capable of being converted to L.P.G. In addition 3,327 truck transports with a total capacity of 10,147,000 gallons were in service.

Tankers suitable for ocean transport, are used to a limited extent. The construction costs approximate \$500 - \$600 per ton of L.P.G. capacity.

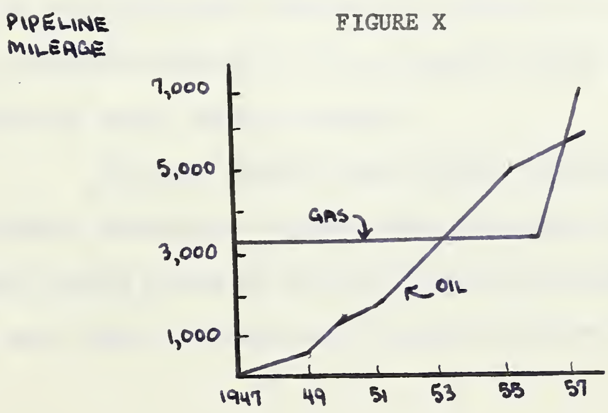
Thus it can be seen that pipeline transportation is a relatively new, though much publicized method, and the more conventional carriers are still the largest movers. In fairness, it should be noted that this table makes no mention to total distances carried.

A more extensive appraisal of the transportation methods in

the U.S. is readily available in most of the trade publications. A full examination is unwarranted in this paper because the Western Canadian market situation is so different from the American picture.

In 1956, Canadian Hydrocarbons took out a permit to build on an 800 mile line from Alberta to Fort William. Total cost including feeder lines approximated $60 million. Their idea was to market the propane in Manitoba, and ship from the Lakeheads to the Eastern market. They originally considered the possibility because the rail cost of L.P.G. from Alberta to Lake Superior was 10¢ per gallon, whereas the cost of pipelining under optimum conditions was 2¢ per gallon. To make the plan feasible, there had to be a deficiency in Eastern supply. The plan was shelved because this shortage did not materialize, and is not likely to develop over the short run. The position of Eastern refineries is strengthened by the growth in crude and natural gas pipelines from Western to Eastern Canada. As long as they get adequate supplies of crude, it will be cheaper for Eastern users to get propane from refineries than to ship it in directly. The following graph indicates the rate of growth of crude and natural gas pipelines in Canada:

FIGURE X



Thus, a greater effort in promoting the sale of crude and natural gas from Western Canada effects the possibilities of L.P.G. adversely in two ways. It increases the supply of L.P.G. and at the same time makes markets more competitive.

It is doubtful if any L.P.G. pipeline will be built eastward from Alberta in the foreseeable future. Besides the marketing difficulties, (there is no assurance that eastern refineries will not drop prices), there are technical problems which exist for L.P.G. but not for crude oil or natural gas. The major difficulty is with temperature extremes which make pressure variance a necessity if the product is to be kept in the desired state - either liquid or vapor. The high construction costs make an L.P.G. pipeline over the Rockies to the Pacific unfeasible. Any pipeline constructed will be to transport the product from the field to large volume consumers in Western Canada as is presently being used from the Devon gas plant to Canadian Chemicals Limited in Edmonton. Tank cars and tank trucks will continue to be the major carriers as they are versatile and can adapt to shifts in demand location without any significant expense. In addition, seasonal demand can be satisfied with a minimum of storage at the point of use. In short, they are more applicable to our situation which has a large number of relatively small volume consumers.

The most obvious export market available is the U.S. Pacific Northwest, Washington, Oregon, Idaho, Montana and Wyoming have an annual market potential of about 75 million gallons. The refineries in the area (Shell at Anacortes, General Petroleum at Ferndale, and Texaco

at Seattle) produce about 35 million gallons per year, with the balance supplied by California and Group III producers.[1] The completion of a Richfield refinery at Washington in 1959 may result in available supply being in excess of demand in the seacoast states. This will probably exclude the California supply, and result in a competition for the L.P.G. market of the interior States (Idaho and Montana) between Group III, the Washington refineries, and Alberta. Even if we are optimistic, and assume that this market can be served most economically from Alberta, and that there are no government restrictions, it is doubtful if any large scale investment would be undertaken to capture this market because of the uncertainty of maintaining it. Probably the seaboard refineries would expand output (by purchasing more Canadian crude so that once again we are competing with ourselves) in an effort to counteract our entrance. Without large scale investment, (i.e. pipelines) unit transportation costs are high so that even though we obtain a market it will never be a big one. The possible saviour is the new Pincher Creek plant close to the American border which will have a minimum of transportation costs.

Japan could conceivably become a market since various Japanese industries are constantly seeking abundant and more economical sources of energy. A refrigeration vessel is now being constructed in Japan for the purpose of carrying L.P.G. from Vancouver to Japan. However, even if this market develops, its demands are not

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1. Group III is the term assigned to the producing areas of Texas and Oklahoma.

expected to be sufficient to warrant the costs of transporting the product from inland areas. Thus Pacific Coast refineries would probably be the source of supply.

CHAPTER VI

CONCLUSIONS

The market situation for propane and butane is peculiar because the supply is not primarily determined by effective demand as is normally the case. Instead, the supply of L.P.G. is determined by the demand for the major petroleum products - natural gas and crude oil. L.P.G. will have difficulty in attaining major product status because its boiling point occurs within the normal range of temperatures and consequently is difficult to handle. Because of the expected increase in Western Canadian petroleum production, the supply of L.P.G. is not expected to be the limiting factor. The major problem for optimum development of the industry is to find markets and develop distribution systems and methods which will serve these markets efficiently.

The markets which seem to afford the best possibilities for expanded use over the short run are combustion engines, rural use and natural gas distribution systems. Over the long run, L.P.G. will undoubtedly be used to an increasing extent as a raw material for the petrochemical industry, and for miscible flood operations.

From a technical viewpoint, propane has advantages over other fuels in combustion engines, providing the equipment is adapted to its use. Consequently the problem is not one of theoretical efficiency, but one of making the engines simple so that equipment costs are not prohibitive. It will be difficult to encourage large manufactuerers to expand the output of engines specifically designed for L.P.G. because of the limited market in which the fuel has an absolute cost

advantage over other fuels. Consequently, the best method will be to find inexpensive methods of converting existing equipment to L.P.G. use. This can be done most easily at the provincial rather than the national level. The work currently being done by the Research Council of Alberta in this area may result in a local private industry which can produce and market these conversion mechanisms.

In rural areas, propane can compete cost-wise with oil, natural gas, and electricity. In addition, it is much more convenient than either coal or wood. Nevertheless, the market has not been developed to anything near potential. This fact is directly attributable to the inadequacies of the merchandising and distribution methods of the industry. Farmers do not realize that advantages of using propane so more dynamic selling methods are necessary. By persuading farmers to use propane for a greater variety of equipment and assuring continuity of supply at stable prices, distribution costs per gallon could be decreased thus providing a larger market and greater profits for distributors. The increased distribution efficiency resulting from more intensive use on the part of the farmer will inevitably make extensive market growth easier.

Using propane for peak shaving operations in natural gas distribution systems does not seem to be applicable to the Alberta situation. However, if other markets cannot be exploited even at minimum prices, propane could be used as a continuous fuel in these systems. The increased cost would be balanced by the revenue obtained from the export of natural gas which would otherwise have been used locally. As long as natural gas is exported on a quota basis this

policy would involve adminstrative difficulties but would be preferable to waste.

As the population of Western Canada increases there will be increase scope for a petrochemical industry in Alberta. New techniques and products will undoubtedly be developed for which Alberta possesses a definite location advantage. However, the growth of the industry is expected to be gradual and only in the long run can it be relied upon as an outlet for surplus production of L.P.G.

If current forecasts of future rates of extraction of Alberta's oil resources can be considered as realistic, the use of L.P.G. for miscible flood operations is not expected to be extensive. In certain reservoir formations it is a definite possibility but these formations are scarce. Until demand is such that it is expected to absorb the output which would be forthcoming using the most efficient normal withdrawal methods, secondary recovery operations are unpractical as a general policy. At present rates of extraction in Alberta, the additional oil output resulting from miscible flood operations cannot be sold for many years, and the costs normally exceed the discounted future revenues. As a consequence, the use of L.P.G. for miscible flood will be restricted to fields with peculiar reservoir formations.

The Pacific Northwest region of the United States appears to be a possible economic market for Alberta's surplus L.P.G. Efforts to reduce political barriers to this market are necessary, and would be most influencial if co-ordinated with demands from the Canadian oil

industry as a whole.

The L.P.G. industry is not the type which can grow by normal expansion into new geographic areas because the size of market where there is an absolute cost advantage as a fuel is limited by transportation costs. This restricted market discourages, to a degree, any large research program which might improve the competitive position of the product. In addition, the firms in a position to finance this research do not have too much incentive as the result may be a decreased demand for some of the other fuels which they produce. Thus as mass production of equipment which can use L.P.G. is unwarranted, unit costs will be high. Generally speaking, the market would be made up of a relatively large number of small volume consumers. Thus, any producer or retailer who expects to expand cannot do it on a gradual basis because (1) the original operating equipment is expensive and have to be purchased immediately, (2) to be economical, storage facilities have to be built with large capactities, (3) trained technicians have to be hired, (4) the stock of equipment has to be carried by the retailer rather than the manufacturer, (5) distribution facilities are expensive as the market is likely to be widely dispersed, (6) there is considerable risk involved because the fuel itself is relatively unproven. These factors have probably led to the relatively slow advance of the product into fields now served by gasoline or diesel oil. In other words, to assume the inevitable confidence, or even existence, of consumers involves a risk which that average firm is not prepared to take. The desire to establish a larger market is further restricted

by the fact that once a market is obtained it is very easy for new firms to enter the industry and capture customers which the more progressive firms established.

Because of the research facilities available for their study, competing fuels have become increasingly efficient as have the engines designed for their use. L.P.G. is thus competing with well-merchandised, nationally advertised products.

The most immediate need is a more co-ordinated organization of firms in the industry. Theoretically, it is the type of situation which is suited to a monopoly type of organization. Assuming a supply surplus the product could be marketed more efficiently if each producer has his own territory (avoid duplication), and the access to centralized research, storage and purchasing facilities. The reluctance of oil companies to finance research may suggest the establishment of a government agency financed by either general oil revenue or interested parties, to undertake research and administer the marketing of the product. However, if the producing and distributing firms could co-ordinate within the framework of the industry a more effective program could be planned. At the present time an association exists but it is ineffective as it has no financial resources or adminstrative power. By expanding this organization, the whole industry would benefit. The association itself could be responsible for such things as advertising, research, storage and co-ordination of policy.

Increased expenditures on advertising are warranted. To be

most effective it should be informative and designed to increase the market as a whole rather than continue the competitive policies which are at present being employed by individual firms in an attempt to capture a larger portion of the existing market from competitors. Suggested media might include farm and trade publications.

To finance and administer research facilities would probably involve a greater cost than the Alberta industry is prepared to pay. However, existing consultant firms, both economic and technical, could be retained to advantage. In addition, governmental departments could be persuaded to expand their facilities for studies of the use of L.P.G. In the long run, the industry might develop to a size which will make the establishment of their own research program feasible.

Common storage facilities could be constructed and more efficient carrier systems used. These and other policies could be handled most effectively by a centralized controlling body. In addition it could operate as a pressure group to force suppliers of equipment to expand the production of L.P.G. engines. It is hoped that the more progressive firms in the industry will attempt to establish and maintain such an organization.

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